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THE

INCORPORATED INSTITUTION OF GAS ENGINEERS

TRANSACTIONS, 1899

EDITED BY

THOMAS COLE, Assoc. M. Inst. C.E.

SECRETARY

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UNIV. OF
CALIFORNIA

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CONTENTS.

	PAGE
LIST OF OFFICERS	5
INDEX TO DISCUSSIONS	7, 9
NINTH ANNUAL MEETING	11
Election of New Members of Council	11
Election of Auditors	11
Election of Members and Associate..	11
ADJOURNED NINTH ANNUAL MEETING	12
Report of the Council	12
Election of Members and Associates	13
Election of Scrutineers	13
Votes of Thanks	14
SPRING MEETING	15
Visit to Staines and Richmond	15
AUTUMN MEETING	17
Visit to Berlin and Copenhagen	17
ADDRESS OF THE PRESIDENT (FREDERICK D. MARSHALL)	23
PAPERS READ:	
Coke-Handling Plant. By T. Holgate	41
Discussion	72
Plates.	
Modern Systems of Retort Heating. By G. P. Lewis	82
Discussion	93
Plate.	
Distribution. By C. C. Carpenter	108
Discussion	111
Plates.	
Incandescent Mantles. By Professor V. B. Lewes	118
Discussion	135
The Practical Working of Carburetted Water Gas. By C. F. Botley	137
Discussion	172
Plates.	
Wind Pressure on Buildings and other Structures. By J. O. V. Irminger	187
Discussion	198
Plate.	

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APPENDIX.

PAGE

Description of the Berlin Gas-Works 203
Plates.

Description of the New Frederiksberg Works of the Danish Gas Company. Communicated by F. D. Marshall 205
Plate.

Description of the Eastern Gas-Works, Copenhagen 207
Plates.

ABSTRACTS OF PAPERS PUBLISHED IN VARIOUS CHEMICAL JOURNALS:

Incandescent Gas Lighting in Munich. By Dr. E. Schilling 211

The Balance Sheet of Heat Units in Coal Distillation. By Herman Poole, F.C.S. 211

Determination of the Vapour Tensions of the condensable Hydrocarbons in Coal Gas. By W. Irwin 214

Depth of Fire in Water Gas Generators. By J. M. Rusby 215

Naphthalene. By Dr. P. Eitner 216

Pumping Gas. By G. J. Roberts 220

Influence of various Oxides on the Luminosity and Durability of Incandescent Mantles. By Herr W. Bruno 222

The Recovery of Nitrogen in Coal Distillation. By W. Carrick Anderson, D.S.C., and James Roberts, F.C.S. 222

Testing Products of Combustion from Furnaces, Boilers, &c. (Abstract from 'Journal des Usines à Gaz,' Oct. 20, 1899) 225

Gas Analysis. (Abstract from 'Gas World,' April 2, 1899) 226

Graphic Method of Determining Illumination. By Hœrst 227

Street Lighting with Incandescent Gas Burners. By Dr. E. Schilling

OBITUARY 230

The Institution of Gas Engineers.

(Incorporated 1890.)

LIST OF OFFICERS, 1899.

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1894 ALFRED COLSON.
1895 CHARLES CLAUDE CARPENTER.
1896 WILLIAM FOULIS.
1897 CORBET WOODALL.
*1898 GEORGE E. STEVENSON.

* Deceased.

UNIV. OF CALIFORNIA

INDEX TO DISCUSSIONS.

Speaker.	Subject.	Page.
Ashworth, J. D.	A Note on Distribution	111
Botley, C. E.	Coke-Handling Plant	78
Botley, C. F.	The Practical Working of Carburetted Water Gas.	178, 186
Broadberry, A. E.	The Practical Working of Carburetted Water Gas.	175, 186
Carpenter, C. C.	Notes on Modern Systems of Retort-Heating	93
	A Note on Distribution	113, 114
Chapman, J. L.	The Practical Working of Carburetted Water Gas.	183
Cross, F. W.	The Practical Working of Carburetted Water Gas.	174
Fletcher, P. H.	Coke-Handling Plant	75
	Notes on Modern Systems of Retort-Heating	100
	A Note on Distribution	111
Foulis, W.	Coke-Handling Plant	74
	Notes on Modern Systems of Retort-Heating	96, 100, 107
Glover, S.	Coke-Handling Plant	77
Glover, T.	Coke-Handling Plant	75
Guyatt, T. A.	A Note on Distribution	113
Harman, E. A.	Coke-Handling Plant	74
	Notes on Modern Systems of Retort-Heating	101
Helps, G.	Notes on Modern Systems of Retort-Heating	96
Helps, J. W.	A Note on Distribution	112
	The Practical Working of Carburetted Water Gas.	172, 185
	Wind Pressure on Buildings and other Structures.	201
Holgate, T.	Coke-Handling Plant	80
	Notes on Modern Systems of Retort-Heating	98
Irminger, J. O. V.	Wind Pressure on Buildings and other Structures.	202

UNIV. OF CALIFORNIA

Speaker.	Subject.	Page.
JONES, J. E. . . .	The Practical Working of Carburetted Water Gas.	186
KING, W.	A Note on Distribution	111
LACEY, T. S. . . .	Notes on Modern Systems of Retort-Heating	101
	The Practical Working of Carburetted Water Gas.	182
LEWIS, G. P. . . .	Notes on Modern Systems of Retort-Heating	98, 105
MARSHALL, F. D. (*Pres.*)	Coke-Handling Plant	78, 81
	Notes on Modern Systems of Retort-Heating	97, 101, 106
	A Note on Distribution	114
	Incandescent Mantles	135
	The Practical Working of Carburetted Water Gas.	180, 183
	Wind Pressure on Buildings and other Structures.	178, 202
MAY, T.	The Practical Working of Carburetted Water Gas.	178
MEUNIER, S. . . .	A Note on Distribution	113, 116
	The Practical Working of Carburetted Water Gas.	178
SMITH, B. W. . . .	Coke-Handling Plant	78
STEVENSON, G. E. . .	Coke-Handling Plant	72
	Notes on Modern Systems of Retort-Heating	97
	Wind Pressure on Buildings and other Structures.	199
WEBBER, W. H. Y. . .	Wind Pressure on Buildings and other Structures.	200
WEST, J.	Coke-Handling Plant	76

INDEX TO DISCUSSIONS.

Subject.	Speaker.	Page.
Coke-Handling Plant	Botley, C. E. . . .	78
	Fletcher, P. H. . .	75
	Foulis, W.	64
	Glover, S.	77
	Glover, T.	75
	Harman, E. A. . . .	74
	Holgate, T. . . .	80
	Marshall, F. D. (*Pres.*)	78, 81
	Smith, B. W. . . .	78
	Stevenson, G. E. . .	72
	West, J.	76
Notes on Modern Systems of Retort-Heating	Carpenter, C. C. . .	93
	Fletcher, P. H. . .	100
	Foulis, W.	96, 100, 107
	Harman, E. A. . . .	101
	Helps, G.	96
	Holgate, T. . . .	98
	Lacey, T. S. . . .	101
	Lewis, G. P. . . .	98, 105
	Marshall, F. D. (*Pres.*)	97, 101, 106
	Stevenson, G. E. . .	97
A Note on Distribution	Ashworth, J. D. . .	111
	Carpenter, C. C. . .	113, 114
	Fletcher, P. H. . .	111
	Guyatt, T. A. . .	113
	Helps, J. W. . . .	112
	King, W.	111
	Marshall, F. D. (*Pres.*)	114
	Meunier, S. . . .	113, 116

Subject.	Speaker.	Page.
Incandescent Mantles	MARSHALL, F. D. (*Pres.*)	135
The Practical Working of Carburetted Water Gas.	BOTLEY, C. F. . . .	178, 186
	BROADBERRY, A. E. .	175, 186
	CHAPMAN, J. L. . .	183
	CROSS, F. W. . . .	174
	HELPS, J. W. . . .	172, 185
	JONES, H. E. . . .	186
	LACEY, T. S. . . .	182
	MARSHALL, F. D. (*Pres.*)	180, 183
	MAY, T.	178
	MEUNIER, S. . . .	178
Wind Pressure on Buildings and other Structures.	HELPS, J. W. . . .	201
	IRMINGER, J. O. V. . .	202
	MARSHALL, F. D. (*Pres.*)	198, 202
	STEVENSON, G. E. . .	199
	WEBBER, W. H. Y. . .	200

The Incorporated Institution of Gas Engineers.

NINTH ANNUAL MEETING.

HELD AT THE OFFICES OF THE INSTITUTION,
11 VICTORIA STREET, WESTMINSTER, S.W.

February 4th, 1899.

MR. GEORGE E. STEVENSON, President, in the Chair.

THE Ballot Lists were handed to and examined by the Scrutineers, who reported the following gentlemen elected:—

As President—Mr. Frederick D. Marshall.

As Vice-President—Mr. James W. Helps.

As Members of Council—Messrs. T. Holgate, T. S. Lacey, and Geo. Winstanley.

As Auditors—Mr. Magnus Ohren and Mr. Alfred Lass.

As Members—Messrs. C. F. Botley, G. S. Frith, J. O. V. Irminger, W. McCrae, T. N. Ritson, and J. McK. Rowbotham.

As Associate—Mr. T. R. Murray.

The Report of the Scrutineers, having been moved and seconded, was duly adopted.

The Meeting was then declared adjourned to the 2nd of May for the reading of Papers, and the remainder of the business.

ADJOURNED NINTH ANNUAL MEETING.

HELD AT THE INSTITUTION OF CIVIL ENGINEERS,
GREAT GEORGE STREET, WESTMINSTER, S.W.

May 2nd and *3rd*, 1899.

MR. FREDERICK D. MARSHALL, President,
in the Chair.

THE following Report of the Council, having been printed and circulated among the Members was taken as read :—

"The Council have pleasure in submitting their Ninth Annual Report. They are pleased to record a continuance of the steady progress that has marked the history of the Institution since its formation. As regards the financial position it will be seen by the Balance Sheet that the money in hand at the end of the year shows a considerable increase; the Council have therefore been able to substantially augment the invested funds of the Institution in accordance with the Articles of Association.

"The Summer Meeting held in June last year was marked by the visit paid by the Dutch Institution of Gas Engineers who attended to the number of about 70 members. It is with great satisfaction that the Council record the success of the efforts made to receive and entertain our confrères from across the sea.

"The Council regret that no definite action was taken upon the Report made by the Committee on the question of the Temperature of Gas Measurement, submitted at the adjourned Annual Meeting.

"The amendments of the Articles of Association agreed upon at the Special General Meetings, held on the 15th of June and 13th of July, 1898, have been duly registered by the Board of Trade.

"The Autumn Meeting was held at Manchester, when an

opportunity was afforded of inspecting the various Gas-works of the Manchester Corporation, and owing to the efforts of the President and the members of the Corporation Gas Committee, the visit proved a great success.

"The Council take this opportunity of recording their thanks to those who have contributed to the usefulness of the Transactions, by furnishing abstracts of Scientific Papers and Drawings, and Descriptions of Works.

"The accounts to the 31st December, 1898, have been duly audited, and the Balance Sheet accompanies this Report."

On the motion of the Retiring President, seconded by Mr. C. E. Botley, the Report of the Council, together with the Statement of Accounts, was formally adopted.

The Scrutineers reported that the following gentlemen had been elected to the Institution:—

As Members—Messrs. J. C. Belton, C. E. Brackenbury, W. G. S. Cranmer, W. J. Fuller, H. Hawkins, and G. M. Robins.

As Associates—Messrs. A. Caddick and H. Morris.

Mr. Stevenson then introduced his successor, Mr. Frederick D. Marshall, who took the chair amid applause.

It was proposed by Mr. Foulis, seconded by Mr. Herring, and carried by acclamation, "That the best thanks of this Meeting be given to Mr. Stevenson, the retiring President, for his services to the Institution during the past year."

The President then delivered his Address, for which, on the motion of Mr. J. W. Helps, seconded by Mr. G. E. Stevenson, a hearty vote of thanks was unanimously accorded.

The following Papers were read and discussed:—

Coke-Handling Plant. By T. Holgate.

Notes on Modern Systems of Retort-Heating. By G. P. Lewis.

Distribution. By C. C. Carpenter.

Incandescent Mantles. By Professor V. B. Lewes.

The Practical Working of Carburetted Water Gas. By C. F. Botley.

Wind Pressure on Buildings and other Structures. By J. O. V. Irminger.

It was proposed by the President, and carried unanimously, "That Mr. A. E. Broadberry, Mr. H. Iago and Mr. W. E. Price be elected Scrutineers for the ensuing year."

It was proposed by the President, seconded by Mr. C. D. Drury "That the best thanks of this Meeting be given to the Authors of the Papers."

It was proposed by the President, seconded by Mr. Guyatt, and carried unanimously, "That the best thanks of this Meeting be given to the President and Council of the Institution of Civil Engineers for the grant of the use of this room for the purposes of the Meeting."

It was proposed by Mr. E. A. Harman, seconded by Mr. Broadberry, and carried unanimously, "That the best thanks of this Meeting be given to the Council for their conduct of the affairs of the Institution during the past year."

On the motion of Mr. J. W. Helps, seconded by Mr. T. S. Lacey, a hearty vote of thanks was accorded to the President for his conduct in the chair.

In his response, the President proposed that the best thanks of the Meeting be given to the Secretary, Mr. T. Cole, for the manner in which he had performed his duties. This was duly seconded and carried unanimously.

The Annual Dinner of the Institution was held at the Trocadero Restaurant, Piccadilly Circus, on the evening of Tuesday the 2nd of May, the President occupying the chair.

SPRING MEETING.

Visit to the Staines Reservoirs, *May 4th*, 1899.

The day was devoted to an inspection of the new works in course of construction at Staines in connection with the water supply of London. The Members travelled by train to Staines, where they were met by Mr. Basil Ellis and Mr. Maurice Aird, representing the contractors, Messrs. John Aird and Sons, and by them conducted over the extensive works in progress.

The works are being constructed for a joint committee representing the New River, the West Middlesex, and the Grand Junction Water Companies, who will each take a supply from the new intake, which is situated on the Middlesex bank of the Thames, some 300 yards above Bell Weir. From the intake the water will be carried by an aqueduct to two storage reservoirs at Staines, a distance of about two miles. Part of this aqueduct will be open and part closed in; and in its course it is syphoned under several obstructions offered by railways and rivers. The united capacity of the two reservoirs at Staines will be 3,300,000,000 gallons. The total area of the reservoirs will be about 400 acres, and the average depth of the water will be about 31 feet. The water will be pumped into the reservoirs through riveted steel pipes, 6 feet 3 inches and 8 feet 8 inches diameter, which are supposed to be the largest yet constructed. The excavated material will be used to form embankments for the reservoirs, and the inside slopes of the embankments will be lined to a depth of 15 feet, with a thickness of 5 inches of concrete, to resist the wave action of the large sheet of water. The discharge pipes from the reservoirs will be of cast iron, 5 feet in diameter, and they will be fitted with sluice valves to enable the water to be drawn off at any desired level. From the pumping station the conduit will be continued to near Kempton Park, where it will deliver into a reservoir having a capacity of about 30,000,000 gallons.

The works have been designed, and are being carried out for

the water companies named, by Messrs. Walter Hunter and Reginald Middleton, MM. Inst. C.E.

Fine weather favoured the Members on this occasion, and the opportunity of inspecting these extensive works was thoroughly appreciated, as was also the kindnesss of Messrs. John Aird and Sons in providing lunch.

It was intended to proceed by launch from Staines to Richmond, but the river trip was cut short at Molesey by lock repairs. From this point the Members made their way to Richmond by road, taking Bushey Park on the way. An interesting day was brought to a fitting close by an informal dinner at the Star and Garter Hotel at Richmond.

AUTUMN MEETING.

Visit to Berlin and Copenhagen, *September 9th*, 1899.

The Members left London on the night of the 8th September, and arrived in Berlin on the following evening. They were met by Messrs. H. W. P. Nugent, E. Thompson, P. G. Ledger, A. F. P. Hayman, and E. J. Hutchence, of the Berlin Staff of the Imperial Continental Gas Association, who represented the Reception Committee of the German Gas Engineers' Association. On arrival, and subsequently, those gentlemen were indefatigable in their attentions to the visitors.

The following day the Members were conducted by road, rail and river to Potsdam, where they were entertained at lunch by the German Continental Gas Association, represented by Dr. Mohr, the manager of the gas-works at Potsdam. On this excursion they were accompanied by representatives of the German Gas Engineers' Association, including Herr von Oechelhäuser, the president, and Dr. Bunte, the secretary. Every facility was given to view the natural and artificial beauties of Potsdam.

On their return to Berlin the Members and a large number of their German professional colleagues were entertained at dinner by the Gas Committee of the Berlin Town Council, at the Kaiserhof Hotel. Herr Stadtrath Namslau, the chairman of the committee, presided, and gave the Members a hearty welcome on behalf of the City of Berlin. Herr Oechelhäuser bade them welcome in the name of the German Gas Engineers' Association. The President (Mr. Marshall) and Mr. Corbet Woodall responded to the cordial welcome. Each English guest was presented with a tastefully bound book containing descriptions and plans of a dozen modern gas-works; in the hope, as Herr Oechelhäuser said, that it would enable them to learn more of German gas-works practice than they could by personal inspection in the time at their command.

On Monday three gas-works were inspected—the Schmargendorf works of the City of Berlin, the Gitschinerstrasse works of the Imperial Continental Gas Association, and the new works of the Charlottenburg Town Council. The Reception Committee placed carriages at the disposal of the Members, and the routes selected in driving to the several works were carefully chosen with the object of affording a glimpse of the main features of Berlin and its suburbs.

At Schmargendorf the Members were received by Herr Schimming, chief engineer of the Berlin Municipal Gas-works. At these works a gasholder of a capacity of 2,750,000 cubic feet, enclosed in an ornamental brick building, was an object of much interest. The works are provided with high and low level railways, the former being carried on light lattice stanchions. The retorts are heated by regenerator furnaces, and there are both horizontal and inclined settings. There are two distinct sets of reciprocating exhausters, one set being used in winter to pump gas to the district holders, about four miles distant. All the pumps are driven by gas engines.

At the Gitschinerstrasse works the objects of interest were the coal-handling machinery and an installation of inclined retorts. Some partially constructed settings gave the Members an opportunity of closely inspecting the details of the furnaces. The coal is unloaded from canal boats and conveyed to breakers by means of steam cranes and grabs. It is taken from the breakers by bucket elevators, and trucks receive it from the elevators and deliver it at any desired point of the overhead storage hoppers. Hydraulic elevators are kept in reserve.

Before proceeding to Charlottenburg, the Members were entertained at lunch by the Directors of the Imperial Continental Gas Association, at the Palace Hotel. The President proposed the toast of the Imperial Continental Gas Association, and Mr. Corbet Woodall, in the absence of any director, replied. On the proposal of Mr. J. W. Helps, the German Gas Engineers' Association were thanked for the manner in which they had organised and carried to a splendid success the visit of the Institution to Berlin.

The objects of chief interest at the Charlottenburg works were a new retort-house, fitted with inclined retorts, and a charging and "drawing" machine. The new retort-house was designed by Herr Schimming, now of Berlin. When

completed, the house will contain sixty-four beds of eights in two parallel rows. The roof is supported principally by stanchions set along the centre of the house; and it is divided into three sections to improve the ventilation. The coal is carried to overhead hoppers by hydraulic elevators and trucks running on rails, band conveyors being held in reserve. The whole design of the house is on a magnificent scale, and the many novel points of detail were closely scrutinised by the Members. In the horizontal retort-house the settings are singles. The operations of charging and "drawing" are performed by one machine, driven by hydraulic power. A pusher pushes the coke out at the back end of the retort, where it is taken up by a De Brouwer conveyor, and by it carried to the yard. The new charge is pushed in by one stroke of another pusher.

After the works had been inspected, the Members were entertained by the Municipality of Charlottenburg. The Burgomaster, Herr Schusterus, gave expression to the pleasure the Municipality had in receiving the English gas engineers. Mr. Marshall proposed success to the Charlottenburg gas-works, and Herr Oechelhäuser proposed the Institution of Gas Engineers.

This concluded the Berlin portion of the programme. The visit was enjoyable and instructive in the highest degree. The Reception Committee were untiring in their attentions to the Members. In addition to those already mentioned, Herr Streichert, Director of the Berlin Municipal Gas-works, Herr Müller, Director of the Charlottenburg Gas-works, and Herren Elster, Silbermann, Blum, Salzenberg, and H. J. Müller, Dr. Frank, and others, contributed, by their kind assistance, to the enjoyment of the Members. To Dr. Bunte especially the Members are indebted for his invaluable assistance in translating the many kind words addressed to them in German.

The greater part of Tuesday was occupied in travelling to Copenhagen, under the genial guidance of Mr. Marshall. *En route* the members were presented by the Danish Tourist Society with copies of a descriptive history of Copenhagen, which forms an appropriate memento of an interesting visit.

On Wednesday the harbour and several works upon the quays were inspected; also the Eastern gas-works of the Copenhagen Town Council and the Stradvei works of the Danish Gas Company. For the inspection of the harbour, the Copenhagen Harbour Board, represented by Captain Dreschel, placed a

steamer at the disposal of the party. The first stop in the round of the harbour was made at the stores of the Danish Coal Company, where a very interesting plant for the unloading, storage, and delivery of coal was inspected under the guidance of Mr. Ostenfeld and his assistants. The stores are built on the Monier system, described by Mr. Marshall in a paper read before the Institution in 1895. The coal-handling machinery was described by him in another paper in 1897.

At these stores there is accommodation for about 60,000 tons of coal and coke, and in addition the coal supply for the Copenhagen works of the Danish Gas Company is received and stored preparatory to being moved by rail to the gas-works. Some 30,000 tons can be stored in Monier bins, and there is room for about the same quantity in a roofed-in space behind the Monier structure. The Monier building is divided up into sections, so that different qualities of coal can be stored separately; and cart-ways intersect the store, so that any quality of coal in stock can be delivered through shoots into the customers' carts. The coal is raised from the ships by means of a grab travelling upon a curved boom, and delivered into trucks running on slightly inclined railways laid along the roof of the store. These trucks run down the incline under the impetus of their own weight, and they can be discharged automatically at any desired point, the place of discharge being determined by the position of a striking block. In its descent the loaded truck lifts a balance-weight, and when the truck is emptied the energy stored up in the elevated balance-weight is sufficient to bring the empty truck up the incline for another load for the hopper, into which the grab delivers the coal for the ship. In the same store coke-breakers, driven by electric motors attracted the attention of the Members.

The harbour grain stores, where the grain is unloaded and handled exclusively by band conveyors, and a Temperley conveyor at work unloading and storing coal, were also inspected. The Temperley conveyor raises the coal in buckets, and tips it at any point in the length of an overhead beam, thus permitting a deep space to be filled without moving the machine.

On finally disembarking, lunch was served in the Langelines Pavilion. Mr. J. W. Helps proposed a vote of thanks to those gentlemen who had thrown their works open for inspection.

At the Eastern gas-works, the method of handling the coke

was an object of much interest. The coke is lowered from the retort-house floor to the yard level by a hydraulic lift, and run on rails to a breaker, where it is sorted and measured ready for delivery. At the Stradvei works the object of most interest was an Intze holder. The Intze holder works in an over-ground annular tank, and the central space beneath the tank is available for storage.

In the evening the Members were entertained at dinner at Skodsborg by the Lighting Committee of the Copenhagen Municipality. Herr Windfeld-Hansen, Director of the Lighting Department, presided. He thanked the Members for coming to Copenhagen, and for the cordial reception given to Danish gas engineers whenever they visited England. Mr. T. May proposed the toast of the Copenhagen Municipality. Mr. J. O. V. Irminger, engineer of the Eastern gas-works, proposed the English Gas Engineers, and Mr. Corbet Woodall replied.

On Thursday the new Frederiksberg works of the Danish Gas Company were inspected, the Royal Danish Porcelain Factory being visited on the way thither. The Frederiksberg works were described by Mr. Marshall in a paper read before the Institution in 1898. The method of handling the coal, the working of the inclined retorts, and the operation of a governor that responds to the demands of the district, as also many other novel features, were inspected by the Members with much interest.

Luncheon was served on the works. Mr. C. C. Carpenter proposed a vote of thanks to Mr. Marshall, to whom, primarily, he said, the Members were indebted for the opportunity of visiting Copenhagen. Mr. Marshall proposed the Directors of the Danish Gas Company, and Colonel Lewin (a director) responded. Mr. Woodall proposed the health of Mr. J. R. Cridland, the local director of the Company.

In the evening the Members were the dinner guests of the Directors of the Danish Gas Company, at the Hotel Phœnix. Colonel Lewin proposed the Municipalities of Danish towns, and Herr Borup, the Obermeister of Copenhagen, replied. Mr. Marshall proposed the Queen's Chamberlain, the Assistant Director of Railways, and the Chairman of the Danish Tourist Society, who had assisted him in making the visit a success. Mr. Helps proposed a vote of thanks to the Directors of the Danish Gas Company, and Mr. Corbet Woodall replied, saying

that the directors appreciated the valuable work done by the Institution and similar associations.

Most of the Members remained in Copenhagen till Saturday, employed in informal sight-seeing.

During the visit to Denmark, Mr. Marshall and his assistants, Messrs. C. J. Müller, A. Edwards, and T. Westenholtz, as also Mr. Cridland and Mr. Irminger, rendered every possible assistance to the Members.

From beginning to end the visit was an unqualified success—as enjoyable as it was instructive. The various works inspected in Berlin and Copenhagen had each of them novel features of technical interest to gas engineers, and the ungrudging assistance given by colleagues in Berlin, and by Mr. Marshall and his staff in Copenhagen, enabled the Members to make the best possible use of the time at their disposal.

NOTE.—*Descriptions and Drawings of some of the Works visited are included in the Appendix.*

THE PRESIDENTIAL ADDRESS.

By FREDERICK D. MARSHALL.

In preparing this address, which it is my privilege to submit to you to-day, I am reminded of the words of the Sage, who, when asked by a certain person what to write, replied—

> "Think not what thou wouldst write,
> But write what thou dost think."

Following therefore this sage advice, I will endeavour to give expression to some of the thoughts which have occurred to me during the long eighteen years I have been abroad—"a big slice out of a lifetime," as one of my predecessors in office remarked. Foremost, I have had no inconsiderable time for speculation on the fallacy of some general opinions, among which may be classed those concerning our great gas industry. The cherished opinion is that we are moribund, having entered on the stage of senile decay, and with many the wish is Father to the thought. Some—the Prophets—predict our speedy relegation to the past, and that our relics will soon form an object of interest in museums, viewed by the effulgent rays of the electric light. These latter are difficult to deal with. You cannot argue with a Prophet; you can only ignore him.

You, on this side of the Channel, are in a position to judge, even better than I am, whether in the history of the gas industry we have ever been in a more flourishing condition, or based on a surer foundation. As far as the Continent is concerned, I am in a position to inform you that the popularity and increase in the consumption of gas is little short of extraordinary; and if I quoted the figures of some of the German, Danish and Scandinavian towns, you might perhaps imagine that I was verging on the romantic. Curiously enough, this great increase—originally due to the gas used for cooking and domestic purposes—is now largely accounted for by use of gas for illumination; and this result is entirely owing to the work

of Dr. Auer von Welsbach. What the gas industry owes to this man it is difficult to realise; and if Britain is proud of her Murdoch, Austria may be justly so of her great Scientist, who has practically saved the illuminating gas industry from annihilation at the hands of its great rival electricity, and who may worthily take a place beside the illustrious Bessemer, the man who revolutionised one of the greatest staple industries the world has ever known. We have groaned, it is true, under the tyrannies of the Welsbach Companies; and Dr. Welsbach has sometimes been reproached by the unthinking as a party to a monstrous monopoly. But this again is one of the fallacies of popular opinion, based on a want of the true knowledge of facts.

It is curious to note how eagerly Continental cities and towns grasped at the Welsbach discovery as a means of better public illumination; and it is still more curious to note how tardy we in Great Britain have been in availing ourselves of its great benefits, wedded as we are to the flickering, flaring fishtail, with its unsightly bulbous regulator encased in—well, gentlemen, when on the subject of the London street-lantern and the London lamp-post I am apt to forget myself, and to become eloquent in expressions unworthy of your President. It is absolutely astounding to foreigners, that in this great city of wealth and culture, acknowledged by the world to be the "hub of the universe," where the æsthetic cult runs amok, where peacock feathers, blue china, and Liberty silks, are considered the necessary concomitants of a blissful life, where your home interiors are Paradises of Art, that the public do not rise as one man and demand the removal from our beautiful thoroughfares of that monstrosity known as the London Lamp-Post.

There is no city in the world supplied with better or purer gas; there are no Engineers in the profession so harassed by restrictions and the "Photometer Octopus" as the Engineers of our great London Companies; there is no public so ruthlessly victimised by that Juggernaut the London County Council for the financial support of its testing-stations; but to what does it all amount? Simply this—that beyond one or two very prominent centres, the lighting of the streets and the railway stations of a petty German or Danish town could put London to the blush. I have the opportunity of bringing with me a photograph of a part of the lighting arrangements of a

small Danish town which I commend to your notice. The Welsbach burners are suspended in globes, producing a beautiful effect; and our experience is that the life of a mantle is considerably prolonged by this arrangement, our books showing a consumption of about $1\frac{1}{8}$ mantles per annum per burner in the pendant lamp against 7 to 8 mantles in the rigid upright lanterns—even when these latter are constructed on the most approved modern principles, storm-proof, and fitted with springs and anti-vibrators.

It has often been said that we are not an artistic people. To this I cannot really assent. We are as artistic as our surroundings will permit us to be; but as I once saw stated in print, our lamp-posts and fittings "give us away," and stamp us as hopeless barbarians. To this I think we must agree.

We have been handicapped heavily by the Welsbach monopoly, whereas on the Continent it has been possible for years past to purchase good mantles at from 3*d.* to 8*d.* each; and it has often struck me, during my visits to England, that the quality and light-giving powers of the mantles employed here do not equal those in use in Berlin, Paris, Copenhagen, and other cities. When there has been a falling off occasionally in those we employ in Copenhagen, it has been found to be due to a too liberal use of the "squeegee," or that the wringing process to which the mantles are subjected after impregnation has left an insufficient quantity of the solution clinging to the cotton fabric. One litre of the best solution as obtained from Austria is assumed to impregnate from 100 to 110 mantles; but I fancy this quantity is often exceeded by unscrupulous preparers of mantles, many of whom manufacture the cotton fabric themselves, and impregnate it with the solution supplied to them. It is, of course, an open secret that mantles used for public and private lighting are not impregnated with equal quantities of the solution. If the mantles are not chemically clean before impregnation, their light-giving durability is greatly impaired.

A celebrated man of science remarked that every project hitherto exploited in reference to uncarburetted water gas "was a child of sorrow." So was the Prodigal Son, but after having been regaled on the animal with a superfluity of adipose tissue, he became a decent citizen; and I hope to live to see the day when uncarburetted water gas will become a commercial

reality. The Welsbach discovery has placed this possibility within reach; and the experiments of Dr. Strache in Vienna are being watched with enormous interest.

The Strache process is, as you are probably aware, based on the production of uncarburetted water gas from coal, and not from coke. The top of the Strache generator is fitted with a chamber in which the coal is distilled, and the volatile products mix with the superheated steam, and pass over the fuel in the lower part of the chamber, where they are decomposed into hydrogen and carbon. The hydrogen mixes with the water gas formed simultaneously. The useless liberated carbon is found in the scrubbers, and is no doubt a considerable nuisance.

Strache gas is richer in hydrogen than ordinary water gas, and thus more valuable for illuminating purposes. It is said that 66 per cent. of the heating value of the coal used is available. On account of the great heating power of the gas, the effect is much higher with Welsbach mantles than with coal gas; and according to reliable tests, the energy per foot of Strache gas is about 18 candles. The gas yields a beautiful mellow light, and does not alter the tint of coloured articles. The small consumption of gas evolves very little heat; the heat evolved being about one-third of that evolved from Welsbach mantles and coal gas. The gas is rendered odorous by means of "carbylamine"; and the most minute escape can be easily detected.

The Dellwik process is likewise attracting much attention. As you may know, the duty on crude petroleum oils precludes their use on the Continent for enriching purposes. Consequently every effort is being made to employ benzol, which is a home product, and can practically be obtained in unlimited quantities. At the Königsberg works, an installation on the Dellwik plan has been in operation since November 17, 1898; 1½ million cubic feet having been produced. This gas was carburetted at the inlet of the holder by benzol; 5 lbs. of benzol being used per 1000 cubic feet. The illuminating gas is about 16 candles.

In working, 1 lb. of coke produced 1 cubic metre (35·3 cubic feet) of water gas, the caloric value of which was 5000 at 18° C. No condensed benzol was found outside the works or in the plant; and there was no trace of naphthalene on the works or during the time the plant was worked.

With benzol at 1*l.* 16*s.* per 100 kilogrammes, the gas costs about 1*s.* 6*d.* per 1000 cubic feet into the holders. Only 28 per cent. of Dellwik gas could be added to the coal gas, on account of trouble connected with the regulation of the Auer burners and cooking-stoves in the district.

Unquestionably, any system that can use benzol is worthy of great consideration; but whether we take the Lowe, Dellwik. or Strache process, there can be no doubt that water gas must be considered the great ally of coal gas. It appears to me that the calorimeter will soon supplant the photometer as the criterion of gas supplied; and the question of gas testing be reduced to a more straight-forward operation than the highly controversial one it is at present. The question of supplying rich or poor illuminating gas will soon admit of no argument, as within a short time, with water gas making progress, *heat values or calories* will form the objects of appreciation.

Respecting the comparative cost of sources of light, the following table, compiled by Herr Wedding, and which I have been at some pains to verify, puts the matter very fairly, and shows that, whatever may be said to the contrary, the economy of gas consumed in incandescent burners cannot be gainsaid.

Illuminating Agent.	Burner or Lamp.	Heat Expended per 1000 Candle-Hours.	Cost of 1000 Candle-Hours.	
		Calories	*s.*	*d.*
Coal gas	Flat-flame burner	66,500	2	1·60
"	Argand burner	50,000	1	7·40
"	Regenerative burner	18,400	0	7·03
"	Incandescent "	10,000	0	3·84
Spirit	" lamp	10,600	0	8·00
Petroleum	1-inch ordinary burner	32,000	0	8·80
"	Incandescent lamp	13,750	0	3·00
Acetylene	..	8,900	0	4·40
Electricity	Incandescent lamp	2,600	1	9·75
"	Arc light	370	0	3·10

Technical education has absorbed much of our attention of late; and on this side alarmist cries are in the air, almost to the extent of panic, because it is asserted that we are lagging behind in this matter, and that the opportunities for the technical education of the masses are too few. Having taken some pains to inquire into this question, and in view of my

knowledge of what is taking place abroad, I can assure you that, as far as *opportunities* and *means* are concerned, we are quite level with, if not in advance of, any other country in the world. More money than is needed is at our command in this respect; and as regards the excellence of the appointments of our institutions, we are second to none. But, gentlemen, the grave question is, *are those institutions as well attended as they might be?* The statistics I have gathered lead one to fear that they are not so attended; still there is no immediate need for either panic or anxiety, for technical attributes and the power of practical work are inherent to our Nation, and cannot be suppressed or nullified in spite of all that English (or for the matter of that foreign) Trade Unionists can do to the contrary.

From years of observation and association, I am led to offer the opinion—and perhaps do so at the risk of offending some of our national susceptibilities—that where we are lagging behind is in the acquirement of the *higher forms of theoretic science;* and that in this respect the outcome of our higher Engineering Colleges is not what we have reason to expect. The result is very different to that of the Continental Colleges. Take the great one at Zurich, for instance. From his birth, the Continental Engineer is nurtured on cube roots, is swaddled in integral calculus, and by the time he leaves his Alma Mater at the age of (say) 23, he is shedding algebraic formulæ at every step, and emitting conic sections through the pores of his skin! He is a mathematician of the highest order. We may smile, and we often do, at the Continental student, with his Mensurs and his scarred face. But do not be mistaken, he is a force to be reckoned with; and this great knowledge—acquired in Universities which are second to none—"cribbed, cabined, and confined" within the nation seeking scope to assert itself, will challenge us for intellectual supremacy at every available spot on this globe.

There are to-day industrial nations which forty years ago were only agricultural; there are to-day half-a-dozen nations fighting us with a deadly commercial rivalry; and the pent-up, highly-trained mind of the Continental student is helping his country at every step. By the expression Continental, I wish to include the Scandinavian nations of Denmark, Norway and Sweden, but particularly Germany. What is the secret of the incontrovertible success of the German Nation? It is

her discipline and her intellect. Her political and military organisation has made her the most disciplined nation in the world; and the application of this same organisation has tended to make her the most intellectual. This land of iron and blood possesses the finest schools in the universe, and has reached a standard of popular instruction which our own country, together with France and the United States, is laboriously trying to achieve. Popular education in Germany is established on the grand basis of discipline, duty, and self-sacrifice; and it is this spirit of discipline—common to the soldier, the scholar, and the workman—which has made German education the best among nations. The spur of poverty, the imperious necessity of finding an existence, makes every German, however brilliant his University career has been, only too glad to accept an opportunity of using his abilities in any form of practical business—whether that of commercial traveller or soap boiler. I have had the privilege of living in close touch with these people for the last eighteen years; and if I am enthusiastic in their praise, it is only due to honest admiration.

With so many highly-trained intellects at their disposal, it is not to be wondered at that Continental gas companies are able to secure thoroughly scientifically trained men—men who, as a rule, have absolved their polytechnic examinations—and what this means, only those can appreciate who have had an intimate acquaintance with the circumstances. That old saying, replete with misconception, that "an ounce of practice is worth a pound of theory," has much to answer for!

Much is being done on the Continent to raise the standard of efficiency of the gas engineer. He is being elevated to the rank of a specialist; and the German Association of Gas Engineers have established at Carlsruhe a curriculum for the higher training of lighting technicians. The German Continental Gas Association have likewise, at Dessau, established a school for training those back-bones of the profession, the non-commissioned officers or foremen. At Carlsruhe, the programme consists of courses of practical exercises at the High School and at the Carlsruhe Gas-Works; the classes being presided over by Drs. Bunte, Haber and Eitner. At Dessau, the scheme is under the care of Herr Direktör Oechelhauser; and aspirants to foremanship are educated in the fundamental principles of gas making, applied mechanics, the use of steam,

and a knowledge of materials. It is a great work, and is deserving of every success.

The Continental student, whether studying or in employment, is afforded every possible means of visiting other countries, and of visiting works or industries connected with his profession, and for this purpose is supplied with funds either from private sources or by the State. This shows what is being done abroad to attract young students of a higher class to our profession, and to meet the objection raised by my distinguished predecessor in office, Mr. Corbet Woodall, that electricity was attracting a higher-toned and better class of men. Municipalities with whom I am acquainted largely avail themselves of these opportunities; and their young gas engineers return home laden with knowledge, all redounding to the strength and *independence* of the undertakings with which they are connected. The City and Guilds of London Institute examination has done much—very much—to increase the attractions of gas engineering, and to raise it from a mere "rule-of-thumb" profession to a place it should, and eventually must, occupy among the higher branches of engineering and chemical industry.

I crave your pardon for having occupied your time by such a long dissertation on matters educational; but it is a question that is uppermost in every thoughtful mind, and to me personally the subject has a great fascination. The consideration of the foregoing brings me to a matter concerning which I invite your attention.

Closely allied to the education of the gas engineer is another question I beg leave to submit to you, and that is the idea of instituting a National, British, Gas Laboratory and experimental Gas-Works. Our industry is perhaps one of the wealthiest, and we cannot plead want of means. At this laboratory and gas-works, students would be educated, and experiments and research in the higher branches of gas physics and chemistry be carried out, under the daily and *constant* direction of our ablest professors, who have made the study of gas science their own. I have been reading the "Proceedings" of the Society of Chemical Industry, and the able address of Dr. Clowes, F.C.S.; and I am stirred to appeal to you on this matter (which has been uppermost in my mind for many years) by what is being done by the local Chemical College at

Nottingham. If the gas industry is to be lifted to the scientific level of other kindred industries, it *can* only be by means of patient research conducted on well *defined lines*, and not by *sporadic* individual effort; for it cannot be expected that men who are weighted by the mind-wearing responsibility involved in the management of a large undertaking, should devote the time necessary for chemical research.

The profession is under the deepest debt of gratitude to the late Dr. Letheby, and Messrs. Fewtrell, Hartley and Wills; also to Dr. Frankland, Professors Vernon Harcourt and Lewes, and Messrs. William Sugg, Lewis T. Wright, and others. But the help rendered by these gentlemen, great as it has been, is insufficient for our needs.

In this respect we are now owing much—far too much for our national pride—to foreigners; and though we are filled with admiration of the epoch-making works of Siemens, Klönne, Gruneberg, Bunte, Lowe, Coze, Langhans, Solvay, Kern, Bandsept, Denayrouze, and Welsbach, it would have given more satisfaction if these honoured names smacked a little of the Anglo-Saxon.

That more research is necessary is evident from the fact that the phenomena of the evolution of gas from coal is still a partial mystery, and the knowledge we do possess is too empirical. The very common phenomena of stopped ascension-pipes has never yet been satisfactorily explained or the remedy therefore *really* discovered; the action of the condensers is imperfectly understood; and the presence and cure of naphthalene deposits is, broadly speaking, a speculation, and from the fact that the recent report of the committee on the question of the effect of temperature on gas measurement is too inconclusive and vague to be of great scientific value, or to furnish formulæ for the enunciation of any law on the subject. Some of us have doubtless occasionally had differences of opinion with colliery proprietors, and have had the astounding temerity to question the value of the coals supplied to us. We have been confronted by those well-known printed analyses issued by two well-meaning and representative men of the profession. No one questions the *bona fides* of these gentlemen; but we know that in many instances these analyses, as representing the coal we receive, are as near facts as the fairy tales of M. de Rougemont. In this respect alone a national testing-works would be

of infinite value, and might perform the blessed office of establishing peace on earth and goodwill between those antagonistic atoms the gas engineer and the vendor of coals. It has been entirely due to years of patient research that Dr. Welsbach has been able to lay bare the secrets of the powers of the refractory earths; and it has only been by means of incessant research that the Germans daily evolve dyes more beautiful than ever from our coal-tar, and have thus gained control of an industry which until a few years ago was distinctly British.

I therefore earnestly appeal to you, gentlemen, to take this suggestion under your consideration, and to inaugurate the coming century by the establishment of a national gas research laboratory and works, out of funds guaranteed by British gas undertakings. We have hitherto held—and do now hold—the proud position of being at the head of the world's gas industry, commercially and technically. Others are, however, striving eagerly for this position; and it therefore behoves us to strain every nerve to maintain our supremacy.

It may be of interest to compare the English and Continental methods of production, and what our *confrères* consider a *fin de siècle* gas-works. A short time since, the Municipality of Malmö, in Sweden, invited international competitive designs for a modern works capable of carbonizing 14,000 tons per annum—not a large works, but one that would give scope for modern improvements. In company with the Engineer of the Stockholm works and the Engineer of the Charlottenburg (Berlin) works, I was invited to act as judge; and I accepted readily, being most anxious to see what was forthcoming.

Eight sets of designs and specifications were sent in—three German, one Swedish, one Danish, one Hungarian, and two English. A nice little international *pot pouri!* The eight sets of designs comprised some 200 detail drawings; and it required six days of solid work to come to a conclusion, such was the general excellence of the designs.

Now perhaps you know the story of the three professors—an English, French, and German—who were required to examine their respective classes concerning the anatomy and habits of the camel? It struck them that a more intimate knowledge of the animal itself might profit them personally, so the Englisman proceeded to the Sahara with his hunting traps, and shot one; the Frenchman adjourned to his *Jardin*

d'Acclimatation and studied the beast in captivity; while the German professor retired to the sanctity of his study and out of the depths of his inward consciousness *constructed* what he considered a *fin de siècle* animal! Well, we were somewhat in the position of these professors; and before we could judge others, were compelled to construct our camel.

Putting aside the local requirements of coal transport and storage, all clearly laid down in the programme, we argued that a perfect gas-works of an annual (commencing) capacity of 14,000 tons, should be:—

Retorts.—149 horizontal retorts 10 feet long, equal to a capacity of 6500 cubic feet per retort per diem, or 125 inclined retorts of 8000 cubic feet.

This number would include a reserve of 10 per cent. The inclined retorts to be about 12 feet long. Three International Judges were thus in favour of *short* inclined retorts.

Coke Quenching.—In the immediate vicinity of the retort-house a coke-quenching space, equal to half-a-day's maximum production, or, say, 520 square metres (3500 square feet) of area.

Coke Stacking.—A further stacking place, equal to 43,000 hectolitres = 858 square metres (9500 square feet) space. Coke to be stacked 16 feet high.

Coke Conveyor.—The coke to be transported from the retort-house to the stack by a conveyor of the "De Brouwer" type, quenched as much as possible *outside the building*, and conveyed direct to the coke-crushing and sorting machine, which must be able to deal with 1000 hectolitres per working day.

Condensing.—All condensing, tar extracting, and purifying apparatus to be in buildings, the temperature of which can be placed under control.

For every 1000 cubic metres (3500 cubic feet) of gas produced, an air-cooling surface of 3 square meters and a water-cooling surface of 1 square metre to be provided.

Order of Apparatus.—The apparatus to be planned in the following order:—Retorts, condensers (primary), exhausters, condensers (secondary), tar extractors, scrubbers, washers, purifiers, meter, holder.

Reserve.—Exhausters and tar extractors to be duplicated.

Scrubbers and Washers.—The volume of the scrubbing or washing apparatus to be not less than 6 cubic metres (212

cubic feet) for every 1000 metres (35,000 cubic feet) gas; and there must be at least two subdivisions of this order of plant.

Purifiers.—At least four sets of purifiers for oxide of iron. The area of each purifier to be not less than 1 square metre (10·8 square feet) for each 1000 cubic metres daily maximum production.

Revivifying.—The revivifying floor to be not less than 20 square metres (215 square feet) per 1000 cubic metres of maximum production. If a mechanical oxide turner is used, the space may be curtailed 25 per cent.

Station Meter.—The station-meter drum not to exceed 100 revolutions per hour; the production per hour (maximum) being reckoned at 1200 cubic metres.

Gas Speed.—The speed of the gas not to exceed 3 metres per second. The minimum allowable pipe dimension being $\frac{1200}{3600} = \frac{1}{3}$ cubic metre per second, $\frac{0 \cdot 333}{3} = 15$ inches.

Regulator and Connections.—These to be constructed to pass a maximum of 2000 cubic metres (70,630 cubic feet) per hour.

Tar and Ammonia Tank.—Estimated that 1 cubic metre of coal = 120 litres of ammoniacal liquor and 45 litres of tar—together 165 litres—14,000 tons = annually 630 cubic metres of tar. Tar tank to contain, therefore, 600 cubic metres, or one year's supply. Ammonia tank to contain 1680 cubic metres. Assuming there is a sulphate apparatus erected, the ammonia tank to contain 16 per cent. of 1680 cubic metres, or 270 cubic metres. The sulphate of ammonia apparatus to be equal to 10,000 litres per diem.

Pumps.—The usual and necessary pumps.

Water Tank.—To contain 30 cubic metres.

Workmen.—Rooms for fifty men, with warm baths, refectory, &c., &c.

Shops.—Smith's shop, carpenter's shop, and usual offices.

Such was our "camel"; and the designs more than fulfilled these conditions. The drawings themselves were (excepting the English) of the most elaborate and beautiful description, and as I thought it might interest you to see these plans, the Town Council of Malmö have been good enough to entrust them to my care, and I now have the pleasure of presenting

them for your inspection. The first prize went to Herr Montgomery, of Malmö; the second to a Hungarian Engineer (Herr Bolz, if I remember rightly); and the third to Herr Klönne of Dortmund.

Regarding the estimates for the works, it is curious to record the extreme variations there appear to exist in engineers' minds respecting what a works should cost. For instance, the one in question was estimated by the competing engineers as follows:—

For a works carbonising 14,000 tons annually—

£	£	s.	d.	
A.—52,778	3	14	0	per ton.
B.—59,166	4	6	0	"
C.—48,111	3	8	0	"
D.—25,444	1	16	0	"
E.—31,055	2	4	0	"
F.—54,722	3	18	0	"
G.—50,944	3	12	0	"

This did not include gasholders (already provided), nor the cost of site or fencing in the same.

The scheme costing 50,944*l.* was accepted—the Swedish one. The English estimates were for 25,444*l.* and 31,055*l.* respectively; but it was quite out of the question that the works could have been built for these prices.

Generally speaking, the works were planned quite in accordance with English ideas; and I may say there were very few improvements on English methods—certainly not in carbonising or purifying. Where, however, we may venture to take a lesson is concerning the process of *condensing* and *tar extracting*. It is the Continental practice to place nearly all the condensing and washing (scrubbing) apparatus in buildings the temperature of which may be regulated; and the apparatus is not thus exposed to the vagaries of the sun and wind. The removal of tar by special apparatus on the impact system is a *sine quâ non*, as it is argued that it is wrong—radically wrong—to employ condensers for purposes other than to reduce temperature, or scrubbers and washers to extract tar, thereby impairing their efficiency, causing them soon to choke, and churning up tar and liquor together so that their ultimate separation is a work of difficulty.

Continental works are more ornamental architecturally speaking, are cleaner and roomier, and the apparatus more

perfectly finished; but there the comparison ends. As money-making machines, English works are more economically constructed, as they are free from superfluities.

It may be remarked that all the designs—Swedish, German, Danish and Hungarian (excepting the English)—were worked out on the metric system; and it has often occurred to me that we English engineers would do well to follow suit. I have read the recent correspondence in the 'Journal of Gas Lighting' on this matter; and I cordially endorse all Mr. Brackenbury has said. Why do we, like the ostrich of mythology, bury our heads in the sands of obsolete traditions and antiquated success, and alone (or almost so) of all nations cling to our chaotic system of weights and measures?

There is a point concerning which the Continental mind is troubled and astonished, and that is regarding the extraordinarily large quantity (many thousands of tons annually) of coke exported from Britain to their shores. It is welcomed gladly by the public, but with mixed feelings by the Continental manager. It is true he realises the fact that he cannot supply the local demand; but it is nevertheless a source of wonderment to him that this useful and smokeless fuel is not more appreciated at home, where, if used in larger quantities, it might contribute to solve that "burning question," Smokeless London. He argues, sadly, that if his consumers are willing to pay some 25*s.* to 30*s.* a ton for this ideal fuel, why, oh! why, do the British public allow such a treasure to leave their shores at some 7*s.* to 10*s.* per ton f.o.b.

The Paris Gas Company years ago—long before coke became a drug in the English market—did much to popularise the use of coke by permanent exhibitions of good stoves, and by the distribution of drawings and pamphlets concerning their use. We have on the Continent excellent and really ornamental slow-combustion coke-stoves—not of the monumental tombstone or "sarcophagus" type one is apt to associate with the old form of German stove. Yes! I know you do not appreciate the word *stove*, and prefer the dear old smoky, wasteful fireplace, emitting blacks like a forge, and in which 80 per cent. of the heat ascends the chimney to warm the stars, and before which we gracefully bask, warming a part of our anatomy in the attitude so peculiarly British. But consider the extravagance compared to a good porcelain stove—Doulton ware if you will—burning but a

scuttle of coke per day. Seriously, much might be done by English companies instituting exhibitions of really first-class stoves to popularise the use of coke, and bring home to rich and poor alike the advantages of this really excellent fuel; and the results of these efforts would soon be evident on the companies' balance-sheets. There must be something economically wrong which permits the vending of so many thousands of tons of fuel to the foreigner at a price out of all proportion to its true value. Personally, I shall only be too delighted to aid, and will ship you a steamer full of stoves—if you will only keep your coke at home! As it is, the export of coke has been the cause of enormous loss to the English companies, and has caused a similar loss to the Continental gas-works. The only people who have really profited are the shipowners (and they are not grateful for coke freights) and the foreign middleman, who turns a nice penny by the transaction.

What a vast field for reflection the words "Old Age Pensions" open up. To us, vigorous and hearty, and blessed with a share of this world's goods, it may not appeal so strongly; but to others what a vision of security and comfort it offers. Legislation on this subject in England seems to have hung fire; and the Royal Commissions appointed to report on the question do not appear to see their way clear.

In 1883 the German works which I have the privilege of controlling came under the Sick Insurance Law; in 1885 the Accident Law was enforced on us; and in 1891, the famous enactment providing for those permanently incapacitated and for the aged—these two measures being complementary one of the other. This enactment makes it compulsory on the German workman to insure at the age of 16 against invalidity and old age. It applies to the entire wage-earning population of Germany, whether male or female, whose wages do not exceed 2*l.* per week. That a law of such vast scope is somewhat cumbersome in its application—as, indeed, all such laws worked under the brass-bound Ægis of German officialism are—can be understood; and were it not for that perfect German organisation, it would be simply impossible of application.

How does this complicated machine work? Every employer of labour must, in paying the wages of an employee over the age of 16, see that he is furnished with a "receipt card." These cost nothing, and are obtained on application

from the nearest police bureau. The cards contain 52 blank spaces; and the employer on paying the wages of his work-people affixes a stamp of a certain value on one of these blank spaces. The stamps, which are of various values, may be obtained at any post office, and are used *only* for insurance purposes. Although these stamps are purchased by the employer, he is at liberty to deduct one-half of their value from his employee's wages. This is, however, seldom done—at least as far as domestic servants are concerned. In the case of factory workmen, the division system is in vogue; and it is thus that the contributions to the insurance fund are borne half by the employer and half by the employee.

Does not the State contribute? Yes, most materially. It contributes 50*s.* per annum to every pension, whether invalid or old age pension; it pays the contributions of workmen while serving in the army and navy; it defrays the expenses of the Imperial Insurance Department; and it effects gratuitously the payment of pensions through the Post Office.

What are the results? *Invalidity Pensions:* Taking a single instance, there are four classes of wage-earners; and these pay respectively the *half of* 7, 10, 12 *and* 14 *pfennige weekly* (14 pfennige equals 1¾*d.*). This insures a workman of the fourth class, paying 7 pfennige weekly, the sum of 20*l.* 15*s.* 6*d.* per annum on attaining the age of 50, if at that age he be capable of further work. *Old Age Pensions:* The weekly contributions in the four classes are the *half of* 4, 6, 8 *and* 10 *pfennige* respectively. A workman of the fourth class, therefore, who at the age of 16 commences to contribute, is entitled on completing his 70th year to an annuity of 9*l.* 11*s.* Not a princely sum, surely; but it forms a welcome addition to the earnings of the old not incapacitated working people, and makes some amends for the diminished vigour of old age. This small annuity is, I may add, the cause of some dissatisfaction.

I have endeavoured to sketch shortly and roughly the working of this beneficent enactment. It is not certain that this law would be adaptable in England, as our social legislation is quite different to that of Germany; but it undoubtedly forms the basis of a law which it appears to me is daily becoming a crying necessity. From my own experience and that of my workmen, I may add that *we* are satisfied; and

in our opinion the best point about the whole is that it is *compulsory*. You will appreciate this word, when you consider the practical impossibility of compelling the British or any other workmen to *voluntarily* make provision against the onslaught of the inevitable old age.

The Continental atmosphere is heavy with impending labour troubles; for you must not think you have the monopoly of life's little worries. The tentacles of mischievous Trades Unionism have spread to every industrial country. Even in peaceful Denmark strikes are of daily occurrence; and the outlook, indeed, is most serious. Prompted by that spirit of humour with which it has pleased Nature sometimes to afflict me, I once in this very room made a flippant remark concerning Mr. George Livesey's great profit-sharing scheme; and I take this opportunity of expressing my regret, for I am now convinced that *the only possible way* of mitigating, if not of entirely allaying, the evils of the devastating conflict now being waged between Capital and Labour, not only in our own industry but in nearly every other, is to follow the lead set by Mr. Livesey.

The directors of the company with which I am connected have for many years past encouraged, by means of a generous system of bonuses and payments by results, applied to both officials and men, a personal interest in the undertaking; and I am of opinion that in every gas-works a similar system should be initiated, and that the men who have by their brains and labour assisted to pay dividends should have their services acknowledged beyond the mere payment of their daily wage. Profit-sharing cannot be carried out on any fast lines, or be subject to State control. It must be more or less voluntary, and based on mutual confidence and honesty of purpose; and England has every reason to be proud of "our" Mr. Livesey, who, by the exercise of his great will and profound common sense, has taken the first step towards solving the greatest problem of the age.

This address is already too long; but before concluding, permit me to express to you how deeply gratified I am at the unexpected honour you have conferred upon me by electing me to the position of your President. There is the well-known danger, when a man leaves his own country for a term of years, of the old saying being fulfilled—"out of sight out of

mind." But it has been my constant wish and endeavour to set this old saw at defiance, and as far as they are concerned to keep in touch with the old friends and comrades of my profession; and I echo the wish expressed in Charles Dickens's story of 'The Haunted Man'—

"Lord! keep my memory green."

The leaves of the Tree of the Nineteenth Century are fast falling around us; and soon the old tree will fall too. Let us all sincerely join in the wish that the new Tree of the coming century will bear, as the ripest and mellowest of its fruit on its topmost branches, a flourishing British Gas Industry.

Gentlemen, in this address I have endeavoured to avoid technicalities, and to carry out the words of the Sage, and "write what I do think." If some of my thoughts jar on your ears, and you feel constrained to gently chide me for my Teutophile tendencies, believe me that I am "in spite of all temptations" a true Englishman—perhaps more so now than when I forsook your shores so many years ago. I am jealous and fearful lest we lag behind; and if to-day I have probed weak spots, let me, in the words of the immortal Bottom, crave your indulgence—

"If we offend, it is with our good will,
That you should think we come not to offend
But with good will. . . .
We do not come as minding to content you,
Our *true* intent is—All for your delight."

COKE-HANDLING PLANT.

By T. HOLGATE.

The Author has had occasion to consider the suitability of various forms of machinery for dealing with the coke from an existing retort-house, and also from one now in course of erection at Halifax, and hopes that a record of his experience and of the information thus compiled may prove the basis of a useful discussion.

The subject is taken to include the quenching, the conveyance from the mouths of the retorts, the screening, sizing, washing, storing, and delivery to consumers; and the Author proposes to refer to the features which present themselves under these several headings and consider how the various forms of plant meet the necessities in each case.

Quenching.—If coke is removed by side-tipping wagons, then a good supply of water is needed as well as a distributor which will deliver a fairly equal shower of water over the area of the wagon. Unless this is the case some of the coke will be insufficiently cooled, whilst other portions will be exceedingly wet. In one case, where these trucks were in use (presumably holding about 10 cwt. of coke), the engineer informed the Author their use was being discontinued on account of this difficulty. In my own experience of trucks holding 6 cwt. of coke, the equal cooling of it has not been found easy. At Halifax the coke is received from the horizontal retorts into a hopper having its mouth at the retort-house floor level, and having at the bottom a door. If the cokeman has an insufficient supply of trucks, he receives the coke into the hopper, otherwise he allows the coke to slide through the hopper into the truck and quenches there. If the operation is not well done by the first-named method, then distortion of the hopper door takes place; and in either case a good supply of water is necessary, the advantages being in favour of quenching in the truck. The

efficiency of quenching in conveyors appears to be much better in the scraper form than in the plate. In the latter the water escapes below the plate, whilst in the former it is retained in the trough in contact with the coke. Where all the coke is passed through screens, then it appears less water need be used than when the coke is delivered without such an intermediary.

Conveying from the Retorts.—The most suitable method for each case must depend primarily upon the relation in position, level and area of the coke-yard to the retort-house.

The following are to a larger or smaller extent in use:—

(*a*) Removal by means of trucks worked by an endless rope, locomotive, horses, &c., upon gauges from 2 feet to 4 ft. 8½ in.

(*b*) Removal by means of conveyors.

(*c*) Combinations of (*a*) or (*b*) with means of elevating, e.g. inclined conveyors, bucket elevators, crane by lifting by grab or bucket.

Method (*a*) has been adopted at Halifax for dealing with the coke from 180 mouthpieces, and was selected because of the contiguity of the railway viaduct to the retort-house, preventing the use of conveyors which must run in straight lines. The use of a wire rope gives elasticity in plan as well as in elevation to a greater degree than would the use of locomotives, with the advantage of a lighter set of girders and standards to support the tramway. The haulage rope is ⅝ inch diameter, 300 yards long, running at ¾ mile per hour. The tension is maintained by a weight of 6 cwt. suspended from a pulley 4 ft. 6 in. diameter (over all). The power is obtained from a shaft in the adjacent workshop, and the driving pulley draws the rope from under the tramway through guide pulleys. The pulleys and rollers are of cast steel, selected from the catalogue of Hadfield's Steel Foundry Company, Limited. The rope travels from G to L, through the tension gear (placed under the tramway) and from L to the driving pulley, and from that back to M and thence to E, completing the circuit to G, as shown on Drawing No. 1.

It will be noticed that at L the trucks must be disconnected, and at M reconnected to the haulage rope.

From G to H the ascent is 1 in 14, from H to S level, and from S to E the descent is 1 in 12·63. For safety, the inclined portions of the tramway are fitted on the ascent with automatic stops at 6-feet centres to prevent running away, and on the descent a brake in the form of a long flat bar 2 inches by

½ inch standing 6 inches above the tramway is required. The trucks used weigh about 7¾ cwt., the frame is 5 ft. 6 in. long, the body 3 ft. 6 in. long by 3 ft. 9 in. broad at top and 2 ft. 4 in. deep. The carrying capacity is 20 cubic feet, equal to 6 cwt. of coke. The trucks are connected in pairs by a piece of chain, the front one is secured by a clip (as sample shown) to the wire rope. It has been designed and made as the result of many tests and to meet the trying conditions of this installation. The clip must be easy of attachment to the rope, it must hold firmly in ascending and descending inclines, it must pass easily the guide pulleys on the tramway, and it must by its method of connection to the truck not allow the latter to overrun the clip when descending. It must also be arranged to release automatically when the truck reaches the screens or the place L where the rope passes under the tramway. By fixing at these points a 1⅛-inch diameter horizontal bar 3 ft. 9 in. long at 9½ inches above the tramway this is satisfactorily done. The adhesion of clip to rope is diminished as the latter wears away, and to compensate this, in the Halifax clip, the wedge action is provided with an adjustable slide, and for still further wear the jaws of the clip have renewable bushes. In addition to specimen of this clip, there are on view clips made by Anderson and Finney, Elswick; Mr. Smallman, Nuneaton; the Sydenham Clip, kindly lent by Mr. Shoubridge. The latter is intended for over-truck rope haulage where the clip does not need to be disconnected from the rope and where a considerable load has to be hauled. The installations at Old Kent Road and the Crystal Palace Gas-works of rope-haulage machinery are very instructive, and should be seen by any engineer contemplating this method. The general arrangements are very similar, and the following particulars respecting the South Metropolitan Gas Company's Nos. 1, 2 and 3 retort-houses at Old Kent Road have been kindly furnished by Mr. Charles Carpenter.

The arrangement comprises a sloping shoot (marked A, Drawing No. 2) upon which the coke falls when drawn from the retort; it is there watered by a hose-pipe from the coke-hole; the front, on tail of the shoot, is fitted with a hinged grating which allows the surplus water to run away. The grating is then opened by means of a lever, and the quenched coke allowed to fall into trucks B, holding about 6 cwt. each. These trucks, which are five in number, are connected to an

endless wire rope and run on rails 14½-inch gauge through the coke-hole up an incline to an elevated railway, where they shoot towards either side on to the ground below. An electric bell indicates to the man who controls the levers when to start, and stop. The endless wire rope is driven by a 12 horse-power gas engine, and put in gear by double fast and loose pulleys for travelling forward or back.

The coke required for charging furnaces is run direct into the furnaces by means of a shoot.

The coal carbonised in 24 hours is 30 beds of 10 × 2 = 600 mouthpieces = 367 tons.

The cost of labour is 4·3*d.* per ton of coal carbonised, and includes quenching and delivering the coke upon a heap 10 to 18 feet high by 172 feet long, the coke being drawn from each side of retort benches 313 feet long.

At Halifax, the cost in wages for quenching, removing to store heap, or screening into hoppers is equal to 4*d.* per ton of coal carbonised. The retorts number ten beds of troughs, nine in each arch, that is 180 mouthpieces with six-hour charges.

The points to be emphasised in connection with rope haulage are as follows:—

1. The adoption of a convenient method of automatically tightening the rope.

2. The use of curves upon the tramway and rope circuit of the largest possible radius. At Halifax, the minimum radius is 15 feet, and upon this part the guide pulleys are required at 1 ft. 3 in. centres.

3. The use of fleeting and guide pulleys of large diameter, and where grooved, those grooved to be turned in a lathe to the exact curvature of the circumference of the rope.

4. The life of the rope depends upon the maintenance of the splice, and this in turn depends upon the flexibility of the rope and upon the angle through which it is bent on its circuit, and upon the number of times per hour that angle is reproduced.

5. The use of a screen which is effective in dealing with large quantities of coke received irregularly.

Where coke is delivered nearly dry and in a fairly continuous stream, the screening operation is simplified, but where trucks are used a very efficient screen is necessary. This point will reappear under the head of screening.

The use of locomotives for removing the coke in trucks on a 4 ft. 8½ in. gauge has, to my knowledge, been used with success in one gas-works, but has since been replaced by conveyors and elevators. With a gauge of about 2 feet it is, the author believes, in use at the South Metropolitan Gas-works, Old Kent Road and Vauxhall, also at Dawsholm Works, Glasgow.

The absence of wire rope is an advantage, but on the other hand, good curves and easy gradients are a necessity. Where these can be obtained with a double line of rails from the coke vault to the various parts of the coke yard the system appears to work well. Details of the system are given in Appendix A.

Method (*a*). Removal by conveyors has in many cases not been wholly satisfactory, on account of the high cost in maintenance, although the saving in labour charges has more than justified the capital outlay. Again, the necessity of working in straight lines and the inflexibility of the arrangement have also retarded their adoption. It is claimed by the makers of one kind of conveyor that will be hereinafter described, that a slow curve can be traversed, because the path is described by rollers placed outside the trough; and further, by the use at the terminals of the conveyor of a rotary section, the flexibility is greatly increased. The cost in wages appears to be less with a good conveyor than with trucks, buckets or grabs.

Pan or plate conveyors, however suitable for dealing with coal, are not so for hot coke. The presence of tar, of coke grit, of water for quenching, all conspire against the durability of the plates, the chain, the bearings, sprocket wheels or other moving parts; and to overcome these adverse elements, the thickness of material has to be increased, with the result that the power required has been unduly augmented.

The wear and tear on plates, chains and pins for same have received attention so that quite a number of varieties in the unit of construction are available. Samples of the following, which are playing an important part in this question, are on view, and particulars of tensile strength, elastic limit, &c., are to be found in Appendix C.

1. Ley's bushed links of chain for elevators and conveyors, made in malleable cast iron.

2. Manganese steel links for elevators and conveyors. They are more free from blow-holes than ordinary steel castings, and

their durability is great in presence of grit, water, or under pressure and friction, but not when heated.*

3. Hunt's patent links for reducing wear on sprocket wheels, made in malleable cast iron. Used for chain drives for elevator and conveyor chains.

4. Hack and Piggott's patent combined pan and link (for hot coke conveyors), travelling over rollers.

5. The New Conveyor Company's chain for hot coke.

6. West's patent chain for running along a central guide, as used at Gaythorn. With this is incorporated the roller introduced by Mr. Hunt.

7. The conveyor chains formed by two lines of links secured to rollers placed outside the trough; the scrapers only being in contact with the coke. The chain used may be ordinary welded links, but the designer, Mr. M. B. Wild, prefers to use links 12-inch pitch of manganese steel, or of Krupp's wear-resisting steel.

8. The links and connecting cross-bars, as used in the De Brouwer trough.

Lengths of 400 feet (say circuit of 800 feet) of this chain may be worked from one driving or sprocket wheel having renewable teeth; and the space occupied in depth for the outgoing and returning chains need not be more than 8 inches.

The place where the hot coke conveyor is most efficient appears to be with its upper surface level with the retort-house floor; but there are varying conditions, such as the presence of furnace shoots, which may require the conveyor to be placed under the floor with light shoots directing the coke thereto. In Mr. Wild's conveyor this use of the shoots enables the rollers and other wearing parts to be kept out of contact with the hot coke, water or tar. The return chain is now often placed above the highest tier of retorts, supported by rollers on a series of brackets and tie-rods, in this way giving an easy curve for the change of direction at each end, and also keeping the chain comparatively dry.

This method may be replaced by an under return chain supported on a path supported by the same frame as the conveyor trough; in some cases on the Continent the return chain of the De Brouwer conveyor has been used to take ashes and

* Full particulars of this material are given by Mr. R. A. Hadfield in Proc. Inst. C.E., vol. xciii. part 3.

clinker from the furnaces and deposit them in an elevated bunker.

In most of the push-plate conveyors the scraper does not bear upon the trough, and this secures quiet working with the wear due to weight only, acting upon the rollers or sliding contacts. It is very noticeable, when watching these conveyors, that the coke is taken bodily forward without much distribution, but, being of a relatively small depth, every part may be quenched by the water sprays placed at intervals over the trough.

Elevating.—The makers of the De Brouwer conveyor state that in Belgium their appliances are effective in carrying coke up inclines of 30°, and that, if found necessary, that angle could be increased somewhat before the coke would cease to be carried forward. Mr. Wild, by using a deep scraper, claims to lift up slopes of 45°. This method of elevating is very convenient owing to the absence of difficulties in feeding; the discharge may also be made at any part of the height. The dead weight moved is small, and the wear and tear should not prove expensive.

Bucket elevators have the advantage over cranes in giving more continuous delivery, resulting in less cost for labour, especially where the point of delivery is constant.

It is necessary that the feeding arrangements at boot, or better into the buckets, should be good. The chain to which the buckets are attached must be of uniform pitch, must not wear or stretch unduly, must have pins and bushes that can readily be renewed, or be so hard as to wear out but slowly.

The weight of the buckets, the chain and the coke, with the inclination, will determine the stress to be borne by each link, and in choosing the type, a material of uniform strength should be found. The chain, perhaps, most extensively used hitherto has been Ley's bushed chain, made of "black heart" malleable cast iron, and having a safe working strength of 2500 lbs. for 6-inch pitch, pattern No. 600, which the makers state is about one-tenth of the breaking strength.

The wear of this chain is stated to be very much less when the material employed is Hadfield's manganese cast-steel links, fitted with forged manganese steel pins.

The wear of the sprocket wheels is very much reduced by

the fixing of a roller upon the pin joining the links, as devised by our past President Mr. Chas. Hunt.

It would appear that the ultimate tensile strength of manganese steel is twice that of malleable cast iron, but the elastic limit of the former is comparatively low. It would not, therefore, be advisable to reduce the sectional area (irrespective of the difficulties in casting of steel) of the manganese steel links, as a permanent set would be induced, such as to cause a jerky action at the sprocket wheel.

For any important installation of elevators it would be desirable to have the links proposed to be employed tested, and only use them for stresses well within the elastic limit. It is further desirable to remember that manganese steel is not recommended by its makers for use where the links are liable to become heated, as the strength rapidly diminishes as the temperature is raised.

Elevators are best driven from the top with a belt, so that in case of unusual strain, slipping may take place rather than a breakage.

Buckets used for coke should have strengthened lips; they should have rollers fixed to axles, the rollers running upon the angle-iron forming the framework of the elevator on the upward and downward paths; they should be placed near to each other, with the intervening space covered by a light plate, so as to keep all dust from the links, and other moving parts.

The shape of buckets and the angle of the elevator should be arranged to give a clean discharge without further devices. The capacity of the elevator must be quite equal to what the conveyor feeding it can ever bring to it, otherwise serious trouble from jamming in the boot may result, and again, the conveyor at the discharge end of the elevator must be quite equal to the work assigned to it. These conditions must, of course, be designed to suit the conditions of discharging from the retorts, which might be almost continuous or very intermittent.

In a number of gas-works the coke is elevated in grabs or in large skips fitted with automatic doors, raised by means of cranes of various types.

In some cases, a locomotive steam crane travels upon an elevated railway, preferably of a wide gauge (up to 8 feet); the crane has motions which enable it to cover a series of circles

sufficient to load into hoppers, into screens, or to the store heap as desired. Where the grab is used it would appear that some breakage of the coke will take place in filling. An instance of a recent installation of a travelling crane upon an elevated railway, lifting a large bucket out of a pit, to serve screens and thence into hoppers, is that of the Higginshaw Gas-works (engineer, Mr. Chadwick).

An extension of this method has been devised and patented by Mr. Woodward, of Manchester.* He places a crane upon a frame or carriage, which carriage rotates upon a path of girders. The crane can also rotate upon the carriage, and the combination of movements enables a large area of ground to be covered to a considerable height with coke, or hoppers may be used, from which carts or bags may be filled.

As an instance of cost of providing a steam crane for dealing with 60 tons of coke per hour, the following particulars will serve:—

Crane jib described a complete circle of 120 feet diameter, maximum rake 120 feet, minimum rake 32 feet.

Weight of coke lifted each time 3 tons.

Coke skips 290 cubic feet capacity, with hinged bottom doors (price about 30*l.*).

Total weight of crane 30 tons. Ballast 12 tons.

Approximate price, excluding foundations and steam supply from works boilers, 1000*l.* (Further particulars are given in Appendix B.)

Perhaps the most suitable form of crane is the cantilever, as employed by Mr. Hack at Saltley Gas-works. Coke from the terminus of the pan conveyor falls into a bucket placed in a pit; the bucket holds 2 tons, and is lifted by hydraulic power, traversed along the cantilever or rotated so as to be deposited at the store heap, into screens for boats, or into screens for railway trucks, or for other receptacles for yard sale.

For purposes of comparison, particulars are given in Appendix B of a crane of this type, designed to lift 3 tons in the bucket to a height of 45 feet, and to describe a circle of 47 feet radius.

In connection with coke-handling by cranes, it will be worth while to consider the cantilever cranes and the self-loading and

* See Patent, No. 25,298 of Nov. 3, 1898.

self-dumping buckets of the Brown Hoisting and Conveying Machine Company of Ohio and 39 Victoria Street, Westminster.

Screening.—The form of screen most suitable appears to depend upon the number of sizes of coke required, the height and length available, the intermittent or continuous stream of material, and the arrangements at the hoppers or other receptacles.

For portable screens, the appliances made by Messrs. Heenan and Froude, Birmingham, or Messrs. Blake, Barclay and Co., of Greenock, are worthy of consideration, but it is to fixed screens driven by power that the following remarks are intended to apply.

Where shaking screens are used, as for instance at the Gaythorn Gas-works, and at many collieries, flat plates with round holes closely spaced appear to be effective, furnishing a nut or cobble of very uniform cubic content. The flat plates are placed at a slight inclination, and the forward movement of the coal or coke, and the removal of the dust, are obtained by a reciprocating motion which is quick in a forward direction and slow in returning.

Another form of inclined screen is that known as Greenwell's patent, made by Messrs. Stanley, Davies and Pollard, of Hyde, and in use at the Saltley Gas-works. The coke is traversed by means of a number of chains placed in parallel lines, and the spaces over which the coke is thus brought are made wider or narrower according to the width of the bars placed between the adjacent chains.

Rotary screens appear to have the advantage in simplicity of their moving parts, and in general arrangement are capable of considerable modification to suit individual requirements. For coal, the Humboldt Engineering Co., Limited, use a number of cylinders (as many as five) placed concentrically, the spaces between each adjacent cylinder being occupied by spirals which deliver the various sizes into shoots. In this way the largest material is first removed, preserving it from breakage. One of these compound screens, to deal with 100 tons of coal per hour, weighs 11½ tons and measures 3 ft. 3 in. in length by 10 ft. 6 in. diameter. Similar rotary screens, but without the spirals referred to, are made by many colliery engineers, and to some extent they are used in gas-works for removing dust and

sorting breeze. They appear to be effective, but where coke is the material screened, and wear and tear great, the complexity of numerous concentric cylinders is a disadvantage.

Where coke is supplied dry and in regular quantities, then a plate periphery with round holes will be effective; but if these conditions do not obtain, then wirework periphery with square or oblong holes will be more effective in removing the dust and small sizes; and better still, if very exact sizing is not required, is a periphery built up of round bars secured to a framework in such a way as to be easily renewed. The method of driving may be by internal shaft, or better by external spur wheel and pinion, or by wire rope, chain belt, &c. The screen should be balanced, and the cast-iron parts rotating upon the supporting cast-steel rollers should be turned up true.

To ascertain the relative efficiencies of two types of screens when fed by coke from trucks holding 6 cwt., the following tests were made at the Halifax Gas-works:—

1. Screen with plate periphery 34 ft. 3 in. long by 2 ft. 9 in. diameter, inclination 1 in 8½. Speed 24 revolutions per minute.

	Length of Plates. ft.	in.	Passed through. Per cent.	
½-inch holes at 1¼-inch centres	9	0	2·5	dust.
1 " 2 "	10	3	16·1	nearly all dust.
1½ " 3 "	10	3	16·4	containing 16 per cent. small.
Through end of screen			65·0	not free from dust.
			100·0	

2. Screen with strong wirework and spaces formed by round bars. Inclination 1 in 15. Speed 24 revolutions per minute. 23 ft. 3 in. long by 2 ft. 9 in. diameter.

	Length of Section. ft.	in.	Passed through. Per cent.	
½-inch bars and ½-inch spaces	4	7	26·0	dust.
1 1/16-inch by 1½-inch mesh	4	7	18·0	of which 6 per cent. was small.
1¾-inch spaces	5	4	30·8	clean.
2¼-inch spaces	5	4	20·5	clean.
Through end of screen			4·7	clean.
			100·0	

The screen adopted at Halifax, as shown on Drawing No. 3, is 2 ft. 9 in. diameter by 35 feet long, and is driven by means

of a ½-inch rope at 17 revolutions per minute. It is supported upon four pairs of cast-steel rollers, 14 inches diameter, placed one pair nearly at each extremity, and the others at distances of 10 ft. 6 in. apart.

The framework consists of four cast-iron rings 5 inches wide by about 3 ft. 4 in. diameter outside, which rotate upon the aforesaid rollers; and in the second one is combined the fleeting pulley upon which the wire rope is placed. Intermediate to these castings are cast-steel rings, 1 inch thick, 2 ft. 6 in. inside diameter, and 3 ft. 4½ in. outside diameter. Connecting each of these rings with its adjacent casting are placed eight 1¼-inch wrought-iron rods with shoulders upon each screwed 1⅛-inch Whitworth thread. The cast-iron rings, the steel rings, and the rods are all machined in the lathe to exact dimensions, and when screwed up form a true circle, balanced, and rotating with the minimum of power. The spaces between each ring (approximately 5 feet long) are filled in with the renewable bars or wirework mesh as desired. The square mesh gives more exact sizes, but the wire is not so durable as the bars.

The section No. 1 is fitted with ⅜-inch round bars with ⅜-inch spaces made up in segments such that eight make up the circumference. These segments are each secured by three ½-inch bolts to the rings, and thus are easily replaced.

Section No. 2 has wirework mesh of ¾ inch square. The wire used is No. 7, ·176 inch diameter. This mesh is fitted inside the framework, and is likewise easily renewed.

Section No. 3 is like No. 2, but the mesh is 1⅛ inch square, made of No. 4 wire, ·232 inch diameter.

Section No. 4 is like No. 1, but the round bars are ½ inch, and the spaces 1¼ inch.

Section No. 5 is like No. 1, but the round bars are ½ inch, and the spaces 1½ inch.

Section No. 6 is like No. 1, but the round bars are ½ inch, and the spaces 1¾ inch.

Sizing.—In some localities, coke of small but uniform dimensions is much sought after, and it appears that this may usually be met by screening without the intermediary of a breaker. Whether the cubes so obtained by sorting only are as good fuel as those obtained by breaking the larger pieces, the Author is unable to say, but they can be obtained more cheaply, accompanied by a lessened production of dust. If

coke is to be washed, it is advantageous to have the same prepared to uniform sizes; this is very marked in the washers having mechanical pulsations.

Coke from retorts charged with coal, mechanically broken, to be handled by West's manual machine, was passed through a screen as last described with the following results:—

		Per cent.	
Passed through $\frac{3}{8}$-inch spaces		13·85	shale, dust and smalls.
" $\frac{3}{4}$ " square mesh ..		8·30	containing 30 per cent. under $\frac{1}{16}$ inch square.
" $1\frac{1}{8}$ " " ..		15·39	free from dust.
" $1\frac{1}{4}$ " spaces		24·00	"
" $1\frac{1}{2}$ " "		12·00	"
" $1\frac{3}{4}$ " "		11·08	"
Over end of screen		15·38	"
		100·00	

Washing.—The preparation of small sizes of coke for smith's fires is one that is well worth doing, but it requires careful attention to detail. Washing by hand riddle appears to be the method adopted in gas-works, but it does not appear impossible to devise a machine which shall do this work efficiently, and at small cost for labour and maintenance. The price of washed coke should, however, always be considerably higher than the unwashed material—not less than 50 per cent.—as the proportion of inferior material removed is often high, and this portion may have but a small commercial value. Hand washing is stated to cost 2*s.* per ton in labour and incidentals.

For mechanical arrangements in washing, the Author has endeavoured to learn the experience of those who have dealt with coal upon a large scale, and the following is the information thus gained:—

In England quite a variety of forms exist, many of native origin, and two that are well known (the Luhrig and Humboldt) are of Continental growth.

The distinguishing feature of the two last named is the use of felspar as the medium of separating the heavy parts from the lighter ones, in a "bash" or jigger. This vessel receives coal (of uniform dimensions from screens) and water. By the oscillation of a piston acting upon the stream of water in which the coal is flowing over a bed of felspar, the dirt passes through the latter and is automatically removed, whilst the coal is elevated into bunkers for drying and loading.

The felspar is intermediate in gravity between the good coal and the dirt, and such is the efficiency of the system that the makers of the plant undertake to remove all free ash not exceeding 1 per cent., and to leave not more than 1 per cent. of coal in the dirt they remove, and to do this at a cost of not exceeding 1*d.* per ton for labour, or 3*d.* per ton all charges including that of interest on capital.

Time does not permit of a more detailed reference to "felspar" washers, but full particulars may be obtained from the Humboldt Engineering Company, of Kalk, Cologne, and the Luhrig Coal Dressing Appliances Company, Limited, 32 Victoria Street, Westminster, as well as Sheppard & Sons, Limited, Bridgend, South Wales.

The last-named firm are also the makers of a breeze and ashes washing machine for separating the good fuel from furnace ashes or clinker. In a town of the West Riding of Yorkshire, where the coke is picked by hand from the ashpan refuse and is then washed, the material is highly prized as being very free from sulphur. The explanation given being that the sulphur has been burnt out during the passage of the coke through the furnace.

The washer which has been recommended to the Author by a number of colliery engineers of experience is that known by the name of Mr. Robinson, of Messrs. Bolckow, Vaughan and Company's works.

It has a great advantage in being able to take coal or coke of all sizes at one operation, and the sizing or screening may be done after washing if desired. In comparison with the "Felspar" system the plant required is less costly, occupies less space, and settling tanks for the foul water are not required. The water is used over and over again, and the cost of circulating the same is not great. The makers, Messrs. Robert Wilson and Sons, Bishop Auckland, claim to treat 400 tons per day of 10 hours at a cost of ¼*d.* per ton for labour, to which, of course, must be added charges for interest, &c.

For 10 tons per hour a conical vessel 5 feet deep and 6 feet diameter at its upper surface is required. The coal or coke is delivered by shoot into the centre of an inverted cone, whilst the water enters under pressure at the lower portion; the mingled water and good fuel pass out by an annular space into the drainage shoot where the good material is collected

into a raised bunker, whilst the water flows to a pump used underneath for re-circulation. The heavy parts collect at the bottom and are withdrawn into a bunker by opening a pair of sliding doors at intervals. This latter operation could, of course, be made continuous and automatic if so desired. The mingling of water is made complete by the uprush from the point of entry, and by an agitator placed vertically, and which also keeps loose the dirt which accumulates.

When inspected by the Author at the Lofthouse Colliery the working appeared quite satisfactory, and he has now arranged for a quantity of gas coke of mixed sizes to be washed and afterwards screened. The gravity and percentage of ash will be determined for each size of the washed material and residue.

The Wood and Burnett washer, made by the Grange Iron Company, Limited, Durham, is a belt travelling along an inclined trough down which water is flowing. The fuel and water enter at the head of the trough, the good stuff being carried by the water to the bottom, whilst the dirt is carried over the top and is received in a bunker. The good material is allowed to drain over perforated plates, then elevated into bunkers, whilst the water is re-circulated.

The Eliot washer, made by the Hardy Patent Pick Company, Limited, is somewhat similar to the last mentioned. As installed at the Thornhill Collieries, near Dewsbury, it consists of a pair of inclined troughs (each of which is worked separately), 60 feet long, fitted with close-fitting scrapers. The inclination is about 1 in 10, the trough 20 inches to 10 inches wide and 7½ inches deep, the scrapers 4½ inches deep at 6¼-feet centres on a conveyor chain. The water enters at the head of the troughs, and the coal midway. The good material passes out at the bottom, and the dirt at the top.

The Joslin's patent washer, made by Messrs. Heenan and Froude, of Aston, is arranged to separate coke from inferior material by scraping from near the surface of water all that floats there. To carry this method into effect an oblong vessel is employed, fitted with an inclined plane, which starting below the water line emerges above the vessel, so as to allow of the drainage of the coke removed by a series of scrapers. The scrapers are perforated, and are secured by hinges to a conveyor chain working over sprocket wheels, so placed above the vessel that the scrapers dip into the water where the supply of

coke enters, and emerge from the water to carry up the inclined plane the lightest and cleanest portion of the coke. These oblong vessels are arranged in pairs, and the precipitated matter is automatically removed from them by a screw conveyor, elevating the same to any height desired out of a channel common to the two vessels before mentioned.

Coke breeze from the Halifax Gas-works has been treated in three of the washers mentioned in this paper with the following results:—

Size.	Percentages.		Specific Gravity.		Ash per cent.		User's Report.
	Good.	Residue.	Apparent.	Real.	In Good.	In Residue.	
Through ¾ inch square mesh (a)	81	..	·451	·973	8·94	..	Very good
	..	19	1·009	1·729	..	66·86	
Ditto (b) ..	84	..	·472	1·007	12·40	..	Moderate
	..	16	·877	1·680	..	55·04	
Through 1½ inch square mesh (c)	58	..	·370	·870	13·3	..	Excellent for use with blast
	..	42	·540	1·129	..	14·1	
Through ¾ inch square mesh (c)	36	..	·404	·844	11·3	..	Excellent
	..	64	·593	1·255	..	23·3	
Through ⅜ inch spaces (c) ..	29	..	·446	·862	9·9		Excellent for light forgings
	..	71	·648	1·265	..	28·5	

(a) Treated in the Wood and Burnett washer at South Hetton Colliery.
(b) Treated in an Eliot washer at Thornhill Colliery.
(c) Treated in an experimental washer at Heenan and Froude's works.

N.B.—The gravity of the coke is affected by its compactness, due to degree of carbonisation, &c., as well as to the percentage of ash in its composition.

Particulars as to the method adopted to determine these figures for apparent and real specific gravities are given in Appendix D.

An examination of the washed coke, and the use of it in a smith's fire reveals the fact that the lightest only has been removed by the Heenan and Froude's washer, and that the residue is a mixture of refuse with a quantity of coke in which pieces of scale are imbedded.

If this residue were treated in a washer in which an uprush of water is maintained, there is no doubt a further separation could be effected, resulting in a second quality of coke with a residue nearly all refuse.

The best all round results will be obtained by purchasing for carbonising nothing but washed or hand-picked fuels, and

when this is accomplished economically, the necessity for coke washing will have diminished.

The use of washed coal necessitates precautions to secure freedom from excessive moisture, and this will probably be obtained better by purchasing in the washed state than by carrying out the process at the gas-works.

Until clean coal can be purchased at an economical rate, washing of the coke will be necessary, and it will be worth consideration whether future plants shall be designed to wash the whole or only the smaller cubes.

Storing.—The storing in hoppers provided with doors for discharging the coke into railway trucks, carts, &c., is a comparatively simple matter, if attention be paid to the headroom required, the stock of coke to be held in proportion to the retort-house production, the quantity of each size of coke that will pass through each grade of the screen, the capacity to be allotted to the washed coke, and that the dropping of the coke must be down shoots to prevent formation of dust. Where only the small cubes are washed, it may be desirable, under certain local conditions, to pass the coke from the screens on to picking belts before depositing in the hoppers, so that the refuse may be removed by hand. Where a large trade is done by retailing in bags, special discharging shoots are advisable for the convenient filling of the bags, and for measuring or weighing the same. The arrangements of Mr. Hunt at Birmingham, and Mr. Braidwood at West Greenwich, are worthy of inspection, and especially in this regard.

Storing of coke in the open (or as at some works in large sheds) may be done in a variety of ways.

1. By lifting trucks by hydraulic hoists from ground level to an overhead railway, commanding at a sufficient elevation the area to be covered, as at Vauxhall.

2. By crane on elevated railway (as at Dawsholm, Higginshaw and other works), or by cantilever or jib crane, or by Mr. Woodward's method as described in the earlier parts of the paper.

3. By a combination of conveyor, elevator and travelling conveyor, rectilinear or rotating.

The reloading and screening of the coke from the store heap is accomplished without extra machinery by method 2, but where large quantities were to be handled under method 3,

it might be worth using an underground conveyor. The proportion of the year's make that has to be loaded up from the heap need not be great, and under ordinary circumstances would be filled by fork or shovel into carts brought alongside.

Combination plants based upon the types before mentioned:—

1. *Gaythorn, Manchester.* Engineer, Mr. G. E. Stevenson, M. Inst. C.E.

The retort-house is fitted with eighteen arches (see Drawing No. 4), each containing six inclined retorts 20 feet long. The trough is 212 feet long by 27 inches wide by 9 inches deep, fitted with West's conveyor links and scrapers combined therewith at 12-inch centres, travelling at a speed of 54 feet per minute. The wear upon the central path raised in the trough is taken by sliding blocks in the chain, which can be renewed when necessary, and by the table of a tee iron, which is also easily replaced when worn. The upper surface of trough is flush with retort-house floor, and the return chain is carried over rollers resting on buckets spaced at 9 to 11 feet centres. Tension gear for adjusting the stretch of chain is provided at the point furthest from the engine and the driving pulleys. The discharge from conveyor trough is by a shoot directed towards the buckets on elevator. The buckets are 16 inches wide, of 28 lbs. capacity, and each alternate one is fitted with an axle, carrying at its extremities a roller of 6 inches diameter bushed with Babbitt's metal. All the principal bearings are lined in the same way and are found to wear less than any other metal, as proved by previous experience at the Windsor Street Gas-works, Birmingham. The links are Hunt's patent at 6-inch pitch, and run at 86 feet per minute. The height of elevation is vertically 37 feet, on incline 52 feet, and is capable of lifting 60 tons per hour.

The screen consists of a flat plate 7 feet long by 3 ft. 6 in. wide, making 160 vibrations per minute, with a travel of 4 inches, at an inclination of 1 in 6. The orifices are $1\frac{1}{8}$ inch diameter placed at $1\frac{3}{4}$ inch zigzag pitch. The cold coke conveyor is 167 feet long, with plates 2 ft. $4\frac{1}{2}$ in. long by 1 foot wide each unit. The ploughs are at an angle of 60°. The motive power is a vertical steam engine of 11 inches diameter and 12-inch stroke, supplied with steam at 55 lbs. per square inch, running at 90 revolutions per minute. The indicated horse-power is 20, required for working hot coke conveyor,

elevator, screen and cold coke conveyor. The general arrangements are shown by the drawings and photographs.

2. *The Smethwick Coke Conveyor* is formed by a tapered cast-iron trough made in lengths from 4 to 6 feet, and fixed conveniently below the mouthpieces of inclined or horizontal retorts. The bottom of this trough has a raised part running all along, to form a small gutter at each side into which the coke dust falls and is conveyed by means of push-plates or scrapers to the breeze or dust-collecting box fixed at the delivery end. The centre part of the trough on which the endless chain slides is formed of Australian "iron-wood" in double strips, the top strip being secured to the under one in a way which admits of easy and cheap renewal. The chain is formed of alternate ordinary oblong links and flat steel section bar links. Each of the oblong links is made from a bar of round steel bent to fit into the openings in the flat bar links. This form of chain is free from pins and the slide gutters keep away the dust and grit from the joints of the chain. The endless chain travels on the wood path all along the trough and round the driving or end drums in the usual way, and back over the rollers carried by hangers under the trough slings or standards. After the round links are threaded through the openings of the flat links, the openings in the latter are closed over by a cover plate, and on the top of this cover plate there is fixed to each flat link another plate of the proper width to work in the trough, and these coke carrying plates are about an inch longer than two links, so that a neat joggle is formed to overlap each plate and present nearly a level steel belt surface on which the hot coke falls to be conveyed. These plates form a moving bottom to the trough by which the coke is conveyed along at about 30 feet per minute. The dust so detrimental formerly to chains unprotected from coke grit, falls between the edges of the plates and the sides of the trough into the side gutters, from whence it is removed by the push-plates fixed at intervals of 4 to 10 feet to the underside of the plates, so that as the conveyor is at work conveying and slaking the coke along the trough, the push-plates or scrapers also scrape the coke dust along the gutters and deliver the same out at the end of the trough.

In the installation of this coke conveyor at Smethwick as shown on Drawing No. 5, the four beds on the right-hand side are inclined retorts, and all the others ordinary horizontal

retorts, and the coke from both is carried in the way already described to the end of the retort-house into the elevator, thence to the overhead conveyor which delivers it through the coke screen to the barges or over the storage yard as shown.

3. *The De Brouwer Patent Coke Conveyor* has been in use on the Continent in Holland, Belgium, Germany and France for several years, and on account of its great simplicity it has succeeded in doing work which has caused many other schemes to be abandoned. By means of simple cross-bars the coke, both large and small, is moved along without turning over or crushing, simply sliding steadily along from end to end of the conveyor and up the sloping delivery end to any desired height.

The De Brouwer Conveyor consists of a shallow trough placed in or on the retort-house floor, and a double length of special chain kept apart by distance-bars at intervals of about 2 feet, so as to run parallel and form the transmitting portion of the apparatus. The trough is made of cast iron, mild steel, or wrought iron, and varies from 20 inches wide for small installations of horizontal retorts up to 2 ft. 9 in. wide for large installations of inclined retorts, the width depending upon local circumstances. The depth of the trough is determined by the style of the floor, but is usually 5 inches, though for wide conveyors 3 inches will answer quite satisfactorily, because the bulk of the coke falls near the centre of the pan, which is made very wide to give ample room, so that no shovelling is required.

The chains are kept purposely as near the side of the trough as possible, because the greater portion of the coke falls in the centre, very little reaching the sides, consequently less wear and tear comes upon the chains. The bottom of the trough is also quite flat and plain, without projections or other causes of obstruction and friction to the moving coke. The bottom plate, usually about $\frac{3}{8}$ inch thick, is riveted to two angle-irons, one on each side forming the sides, and the joint is made water-tight. Then the removable wearing angles or strips are fixed in the corners to carry the chains. All bolts and rivets inside the pans are countersunk, and no projections are allowed. Near each end the pan is bent upwards, so that the quenching water may not escape, and at the delivery end, when the coke requires to be placed in hoppers or railway wagons or on the store heap, the conveyor is bent upwards at any suitable angle and carried to any convenient height; it may then be bent horizontal again

and carried any desired distance. In cases where it is inconvenient to have the return chain carried above the mouthpieces, owing to want of space on account of stoking machinery or other causes, the return chain can be carried back directly under the delivery pan all the way, the total depth of the whole conveyor not exceeding 8 inches throughout.

Water for keeping the chains and pan cool and for quenching purposes is run into the pan continuously while the conveyor is at work. At the commencement the trough is partly full of water throughout its length, but as soon as the coke begins to be drawn it pushes the water before it along the trough, and for some distance up the quenching slope at the delivery end, when the water overflows back over the still hot coke and saturates it, thus completing the quenching. Comparatively little steam is produced in the retort-house until the quenching slope is reached, when large volumes are generated, for the quenching is thoroughly done, and the coke requires no further attention to put it out.

The De Brouwer conveyor transmits its load of coke from the retort-house floor to any height and any distance in a straight line without once dropping it or changing its position, in relation to the propelling bars and the pan of the conveyor. When it becomes necessary to change the direction to one at any angle, the coke need not be dropped more than 1 foot, for the construction of the chain is such that either the top or bottom strand can be used equally well for conveying.

The use of the conveyor as an inclined elevator is nearly always adopted; for instance, at Bruges there are two conveyors, and at Ghent eight, each with an inclined end going up about 16 feet, and delivering at the top. At Ostend there are two conveyors in front of the benches, each with inclined ends going up about 20 feet, besides other installations of the same kind at other works.

At Bruges, the Hague and Ostend, the return chain is overhead. At Ghent, the eight retort-house conveyors have the return under the delivery pan, and nothing can be seen of the conveyor in the retort-house except the shallow trough in the floor, while outside the retort-house the sloping end appears to be a girder of 7½ inches in depth, the whole of the delivery and return being included in that space. In these works the removal of the coke from twenty-four through beds of eights,

arranged in four stacks of six through settings each, is done by the foreman who starts the conveyors by throwing a clutch into gear when required, and the coke is delivered into the yard at a height of 15 feet, and a distance of 35 feet from the retort-house, without any further labour or attention.

One of the features of this conveyor is the chain which is formed of block links alternating with double links, the block links being made especially high to take all the wear due to rubbing on the wearing strips of the pan. The single links are connected in such a manner that wear must come upon full width of the portion passing through the hole in the block link, and they are held together by rivets which are made easy of removal, while being perfectly secure. The difficulty of keeping rivets tight when subjected to variations of temperature has been avoided in the recent De Brouwer chains, by arranging the rivets so that they form no part of the wearing surface, and with the sole function of holding the links in place, so it does not in the least matter whether the rivets are tight or loose.

The load due to the weight of the chain forms by far the greater portion of the work and wear, that due to the coke being comparatively unimportant. A moving weight of 15 lbs. per foot run is attained against at least 30 lbs., with plate or scraper conveyors of the same width and capacity. A conveyor to remove 20 tons of coke per hour would require a trough weighing about 2¼ cwt. per yard, and the chain for a long length of conveyor would weigh about 45 lbs. per yard, including all the moving portion; for a shorter portion it would be about 36 lbs. per yard.

Referring now to Drawing No. 6, Figs. 1 and 2 show the coke conveyor arranged to deal with the coke from nine beds of eights, horizontal retorts, and four beds of eight inclined, 20 feet long. The coke had to be taken out at the end of the retort-house, under a roadway, over a canal, and then to be screened and loaded into boats, or stored on a surface of 120 feet long by 120 feet wide, to a height of 26 feet. The screening and loading plant has been omitted from the drawing, as it was of the ordinary type. The diagram shows the scheme in plan, elevation and cross section near the travelling gantry.

It was proposed to take the coke from the retort-house to

the quenching slope outside, then up the inclined end to the desired height, then over the canal and to a distance of 170 feet from the retort-house wall along a light latticed iron or steel bridge supported on standards formed of 12 inch by 6 inch rolled joists. These joists formed the supports for girders carrying rails on which the travelling span would run, and at about 85 feet span a second line of supports and rails would be laid to carry the outer end of the travelling span.

A simple and light lattice bridge of about 100 feet long would carry the conveyor transmitting apparatus, and the coke could be delivered at the end or at any number of intermediate points. The bridge would be propelled at intervals by hand as the space became filled, and the driving of the sprockets would be by means of ropes passing partly round three pulleys arranged exactly as is usual on rope-power travelling cranes. About 2000 tons of coke could thus be stored without requiring more labour than the services of one man per shift to start and stop the conveyor, and place the travelling span where desired. The total length of the conveyor was about 380 feet from end to end.

No. 3 shows cast-iron or steel troughs fitted with renewable floors and angles, the only parts subject to wear.

As regards the amount of labour required to deal with the coke, it may be said that even in large installations, not more than one man will be wanted for attending to the conveyor and delivering the coke from it.

4. *Design for Coke-handling at the New Retort House, Halifax Gas-works.*

The total length of retort-house (see Drawings 7 and 8), which is intended for inclined retorts, is 266 feet. The settings will number 17 on the north side and 25 upon the south side. The quantity of coal to be charged per hour is estimated as 21 tons, and the quantity of coke as a maximum of 60 tons per hour.

The form of hot coke conveyor shown is that devised by Mr. M. B. Wild, of Aston, adapted in the general arrangement to the requirements of the Author. No form of conveyor has yet been decided upon, so that this scheme is in the form of a proposal.

The large scale cross-section shows the trough as 24 inches to 30 inches wide by 9 inches deep, and manganese steel links

12 inches pitch, with scrapers placed at 24-inch centres, which are connected by a cranked arm to axles carrying on each side a flanged roller 6 inches diameter by 1½ inch wide on tread. The distinguishing feature of the arrangement is the avoidance of wear inside the trough, and minimised wear upon the rollers and pins by placing them out of contact with hot coke or water.

The trough may be made of cast-iron or steel, and is shown supported upon framework placed below the retort-house floor. This is necessary to avoid the shoots which deliver hot coke from the retorts into the furnaces. The coke to be taken away by conveyor will be delivered by shoots in such a way as to cover up the chain and rollers, whilst leaving them accessible from the coke vault. The return chain is shown under the trough, the total depth being 44 inches; but this could, if required, be reduced to 36 inches.

Conveyor A (upon north side).—To consist of a cast-iron trough, 1 ft. 6 in. wide at bottom; the scrapers, of mild steel plate ¼ inch thick, being attached to cross bars, carried at their ends by cast-iron rollers 6 inches diameter, running on rails. The troughs are supported by cast-iron brackets carried by a small gantry of 6 by 4½-inch joists, the return rail being carried underneath by brackets from the gantry. The chain to be of links 12 inches centres and ⅞-inch pins, all of manganese steel.

The driving drums to be cast-iron, of hexagon pattern, and securely keyed to a 4-inch diameter shaft, driven by gear wheels 4 to 1. The trailing drums to be keyed to 3½-inch shaft, carried in tension frames of suitable design for tightening the belts.

Conveyor B.—This is a cross conveyor from end of A to deliver on to C.

The trough is the same as conveyor A, and the scrapers, roller and manganese steel links are of the same diameter as for A. The drums are 14-feet centres, and are carried by special brackets to suit the inclination of 45°.

Conveyor C (on south side).—This conveyor is 248 feet long, and in addition to receiving the coke from its own bed of retorts it receives, at about its middle, the coke from conveyor A through the cross conveyor B.

The cast-iron trough in this case is 2 feet wide at the bottom.

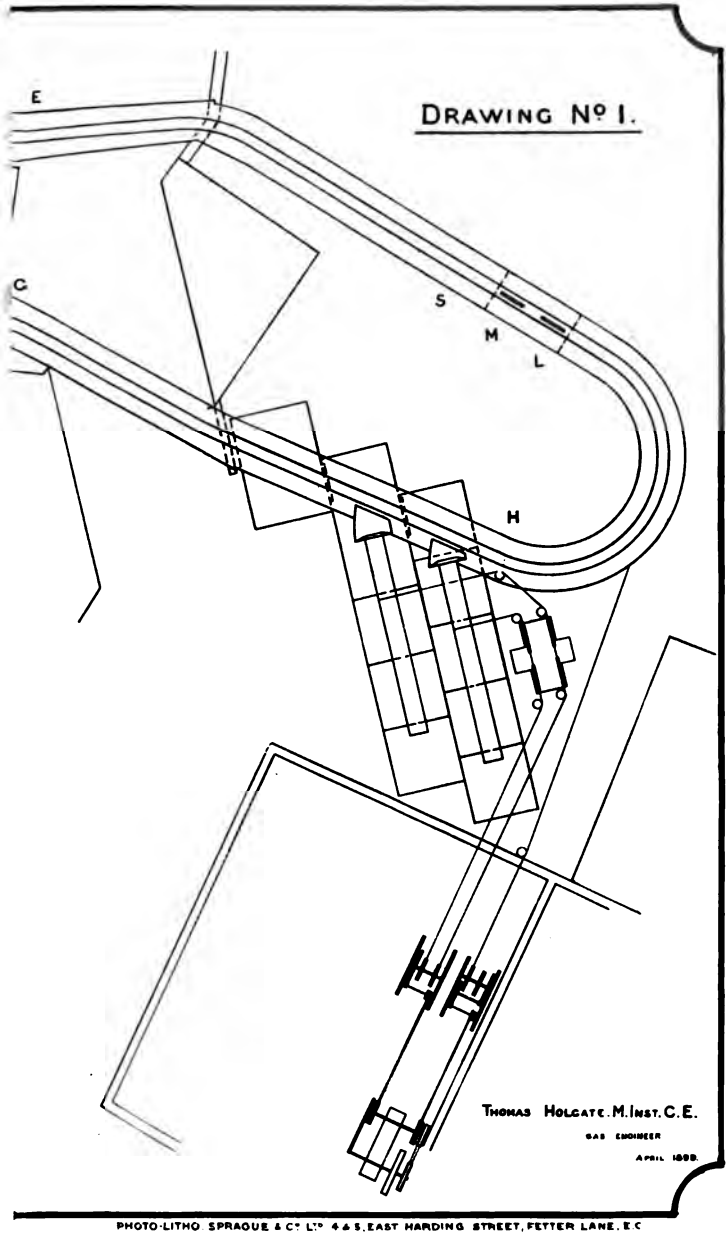
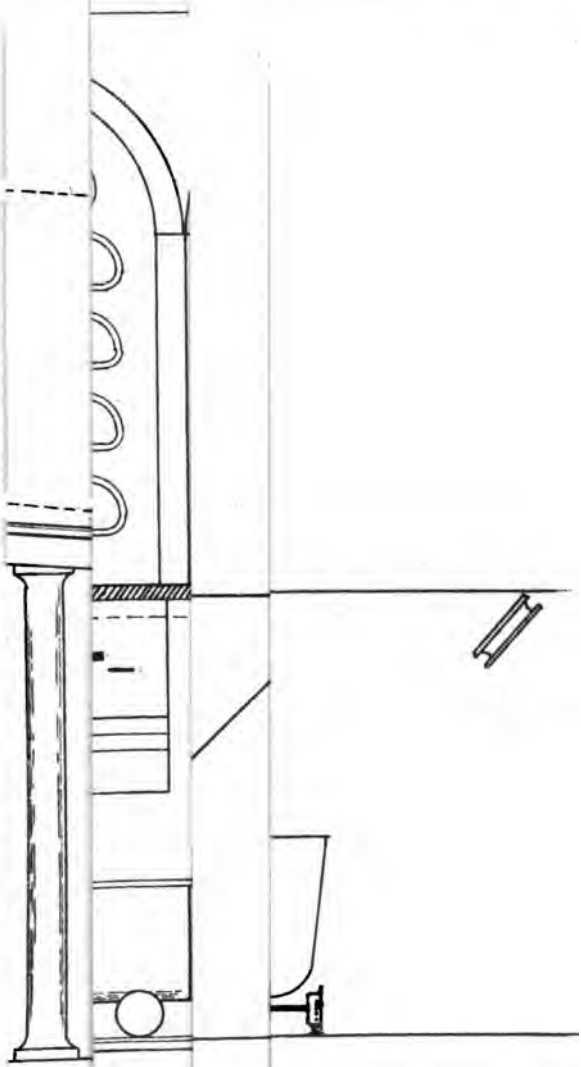


PHOTO-LITHO SPRAGUE & Cº Lᵗᵈ 4 & 5, EAST HARDING STREET, FETTER LANE, E.C

DRAWING No 2.



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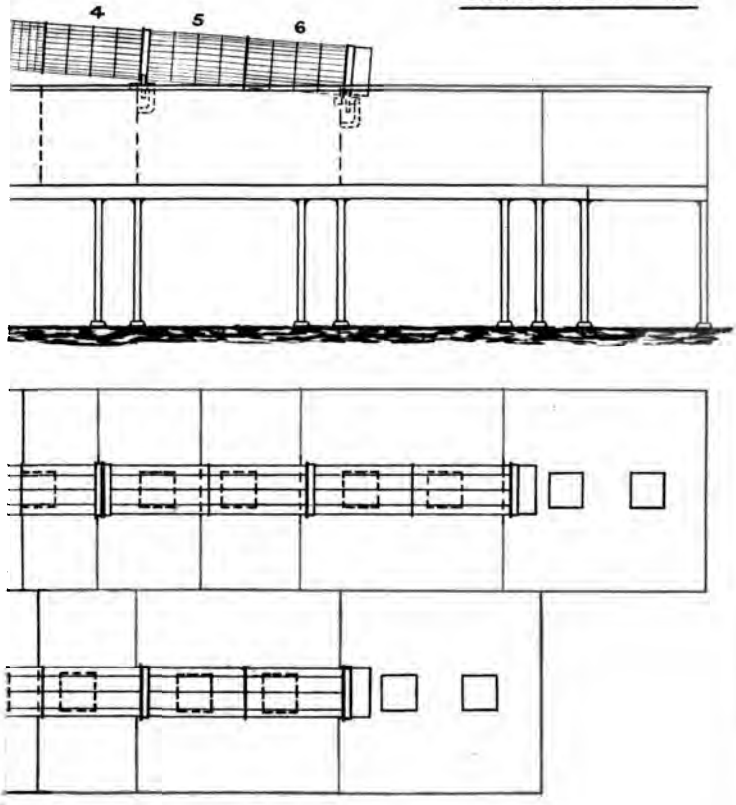
DRAWING Nº 3.



ALIFAX CORPORATION GAS WORKS.

COKE HOPPERS AND SCREENS.

15 20 Feet

THOMAS HOLGATE M. INST. C.E.
GAS ENGINEER.
APRIL 1899

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DRAWING Nº 4.

N GAS WORKS.

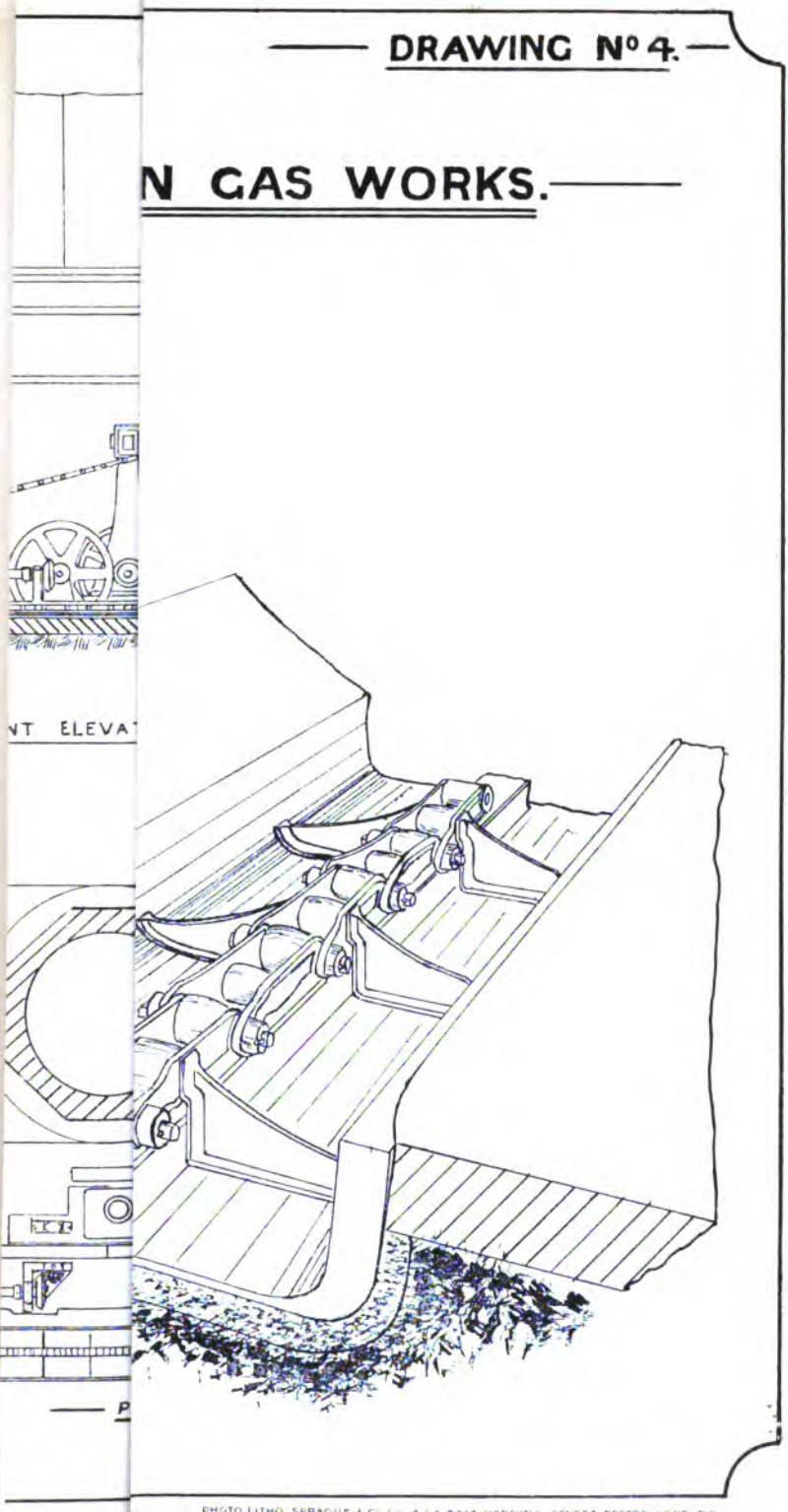
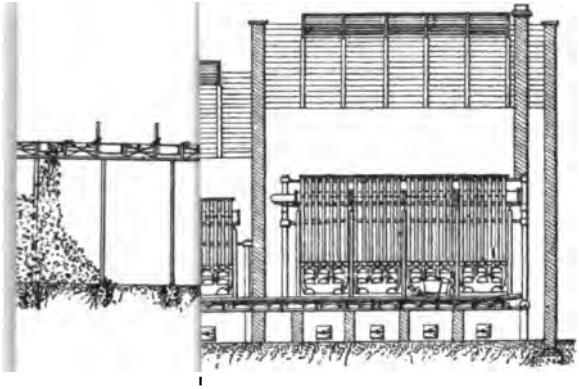
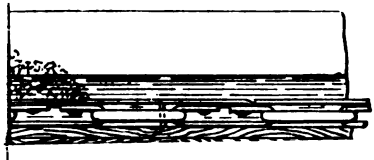


PHOTO LITHO SPRAGUE & C° L° 4 & 5 EAST HARDING STREET FETTER LANE E.C.

S — DRAWING Nº5. —





UWER CONVEYOR. DRAWING Nº 6.

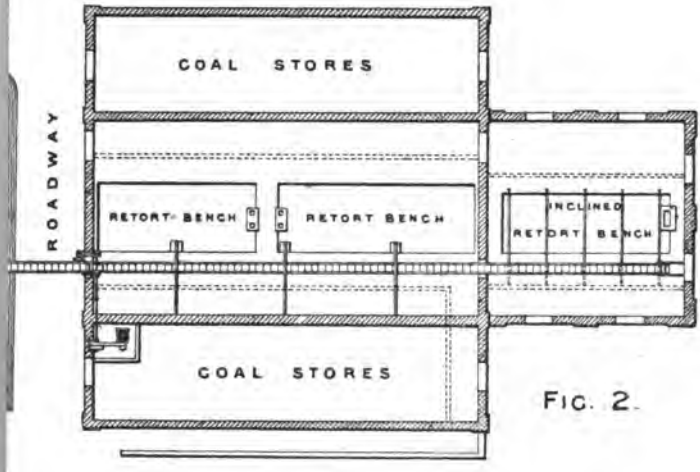


FIG. 2.

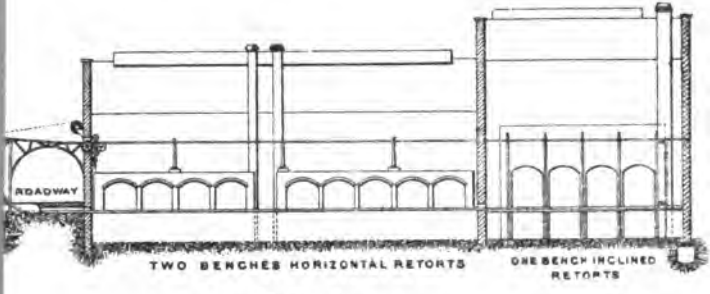
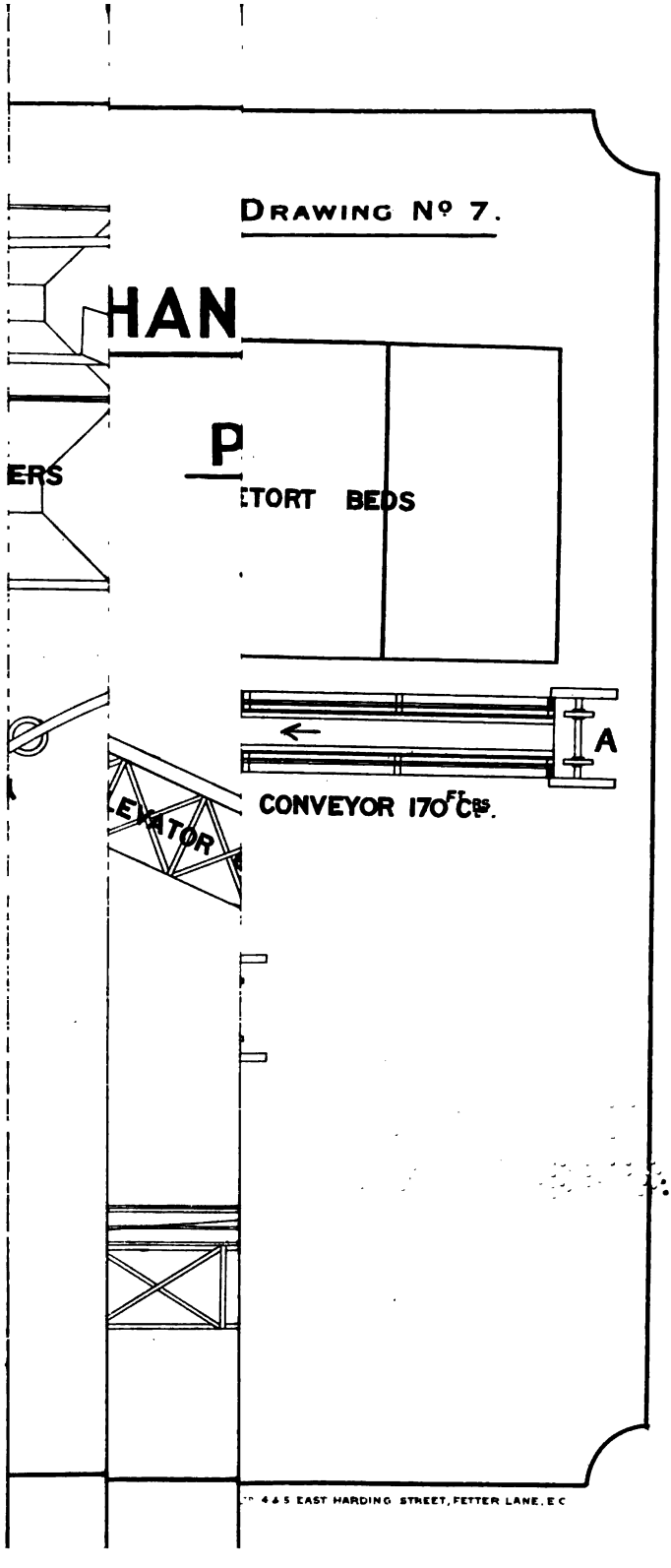


FIG. 1.


DRAWING Nº 7.
HAN
P
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TORT BEDS
A
CONVEYOR 170 FT CRS.
LEVATOR
4 & 5 EAST HARDING STREET, FETTER LANE, E C

DRAWING Nº 8.

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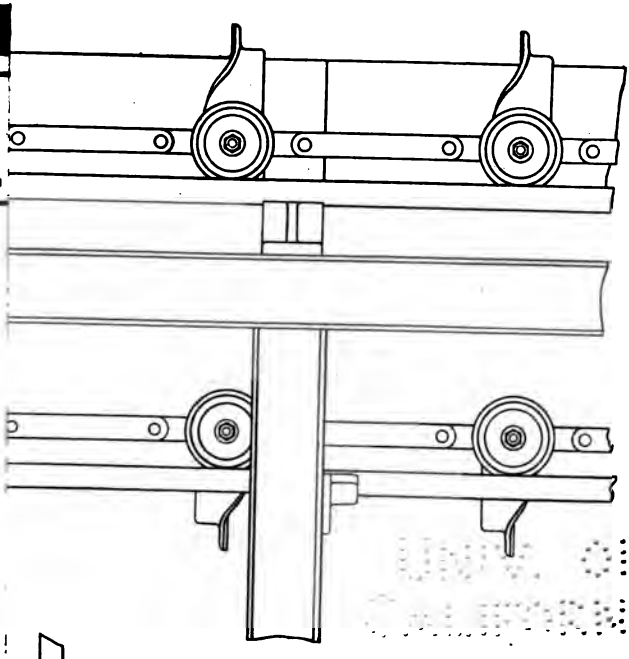
ON.



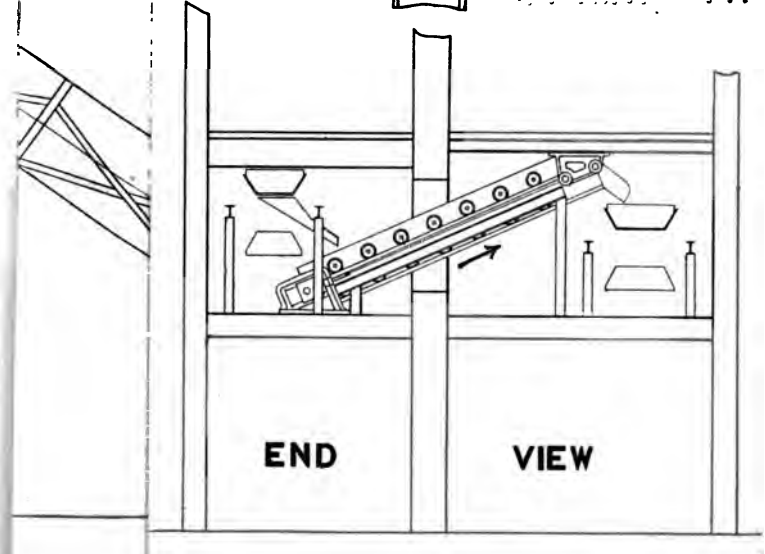


PHOTO-LITHO SPRAGUE & Cº Lᵗᵈ 4 & 5 EAST HARDING STREET, FETTER LANE, E.C

The scrapers are of ¼-inch mild steel plate, and carried by frames on rollers similarly to conveyor A.

The chain is of manganese steel links and pins. The driving shaft of this conveyor is 5 inches diameter.

Shoots.—Shoots of suitable dimensions, and constructed of mild steel plates, are to be provided to conduct the coke from A to B, and from the end of C into boot of elevator.

Elevator.—This is to be of the scraper type, and the troughs, scrapers, chains and rollers to be in all respects similar to conveyor A, except that troughs to be 2 ft. 3 in. wide at base, and the centres of drums to be 66 feet. The height above yard level at end of hot coke conveyor is 9 ft. 6 in., and at top of elevator 45 feet. The elevator of 35° to be carried on a steel framework or girder, supported at the ends, and in the centre by a steel braced column.

Deflecting shoot.—The elevator delivers into a shoot, of which the spout is pivoted so as to deliver into the screens or on to the conveyor D as required. The shoot is constructed of mild steel plates and angles, and is operated by a chain and lever.

Conveyor D.—The troughs for this conveyor are 2 feet wide at the bottom, and the scrapers, driving gear and links are practically similar to conveyor C, the centres of drums being in this case 48 feet. The conveyor is carried by a substantial steel lattice girder, 3 ft. 6 in. deep, at an elevation sufficient to allow the radial arm to describe a complete circle. A footway of planks is carried by brackets from the girder.

Radial arm.—This conveyor, 50-feet centres, is similar in all respects to conveyor D, except that the troughs have sliding doors at intervals in the bottom, in convenient positions for distributing the coke. The conveyor is carried by a substantial lattice girder 3 ft. 6 in. deep, one end of which is pivoted on the top of a central column, which also carries off conveyor D. The other (outer) end is carried by a carriage running on a circular gantry 26 feet above yard level. A footway is provided as in conveyor D. The circular gantry consists of 12-inch by 5-inch joists carried on cast-iron columns.

Rotary screen.—The screen for large coke is be 4 feet diameter by 8 feet long. The screen is carried on rollers grooved to suit the turned angle-iron rings of the screen, and those on one side being keyed to a through shaft driving the

screen by friction. The screen bars $\frac{5}{8}$ inch diameter, set to the required pitch, are secured to the rings by clips, which allow of easy removal of any bars for repairs, &c.

The No. 2 screen for small coke to be 3 feet diameter by 16 feet long, to be in every way constructed similar to the larger one.

Hoppers and Shoots.—The screened coke from No. 1 screen falls into a suitably shaped hopper (20 feet by 20 feet by 16 feet = 6400 cubic feet) of mild steel plates and angles, and is delivered thereby into No. 2 rotary screen. Four hoppers (each 10 feet by 10 feet by 16 feet = 1600 cubic feet each) and shoots are fixed beneath the No. 2 screen to convey the dust and breeze as required.

Washing Boxes.—Two patent coke-washers, occupying together in plan 9 feet by 6 feet, are fixed underneath the No. 2 screen to separate the pure coke from the dirt. The latter is removed by a suitable elevator. The washed coke is delivered by shoots into the storage bunkers.

Engine.—A horizontal engine 16 by 24-inch cylinders, with fly-wheel, to be provided.

The cost of this scheme is approximately 90 per cent. of the hydraulic cantilever crane, described in the former part of this paper.

The points of similarity and dissimilarity may be noted, and the cost in interest on capital, wear and tear, and labour estimated relative to each individual case.

It has been found impossible to make a comparison of the cost for an ideal combination of retort-house and coke yard for the different types of plant; but even if this had been done, the local conditions of each case would be the determining factor.

The Author believes that the appliances now available should allow, in large works, of coke-handling being done for a labour charge not exceeding 2*d.* per ton of coal carbonised.

In conclusion, the Author must express his indebtedness to many of his professional brethren for permission to inspect their works and for the information they have given him, and to makers of plant for the full particulars they have furnished of their respective systems.

APPENDIX A.

Details of the plant in use at Dawsholm Gas-works are given in 'Engineering,' p. 231, of the 23rd August, 1895. Some of these particulars are taken from that source, and others have been supplied by Messrs. Sharp, Stewart and Co., Limited, the makers of suitable locomotives.

Gauge of line 2 feet.

Flat-bottomed rails 30 lbs. per yard, riveted to steel cross-sleepers.

Weight of locomotive in working order 3 tons.

Working pressure of steam 140 lbs. per square inch.

Cylinders 6 × 9 inches.

Four wheels coupled 1 ft. 8 in. diameter.

Wheel base 2 ft. 7 in.

Overall length of engine 11 feet.

Width over platform 3 ft. 10½ in.

Height to top of chimney 5 feet.

Approximate price in the year 1894, 400*l*.

Engine will haul 158 tons on level, or 7¾ tons on an incline 1 in 16.

Maximum incline worked 1 in 12.

Minimum radius of curve on rails 20 feet.

Side-tipping trucks weigh 12½ cwt.; length 5 ft. 6 in.; 4 ft. 3 in. broad at top; 2 feet deep; carrying capacity, 6 cwt. of coke.

APPENDIX B.

1. *Specification of Crane for Lifting Coke in Bucket holding Three Tons.*

Steam-driven jib crane, to lift and deposit 60 tons per hour, by hinged bottom skip or bucket.

Movements.—Lifting and lowering, revolving, jib adjusting, bucket opening and closing, all controlled from driver's platform.

Engines.—Double cylinders 8 inches diameter, 12-inch stroke,

fitted with link reversing gear. Working pressure of steam 100 lbs. per square inch, supplied by independent boilers.

Lifting.—By single purchase, the barrel 18 inches diameter, grooved for $\frac{7}{8}$-inch steel wire rope; a powerful foot-brake provided, and pinion on engine shaft will slide in and out of gear so that only the barrel revolved when lowering.

Bucket Opening.—Gear will be worked by a separate barrel driven from the main barrel shaft by pitch chain and thrown into gear by means of sliding clutch, and controlled by a powerful foot-brake.

Revolving Gear.—Actuated by friction cones worked by hand-wheel and screw.

Derrick Gear.—Worked by spur gearing and fitted with safety catch; the rope will be 1 inch diameter, in five parts.

Jib.—Will be 74 feet long, of steel plates and angles throughout.

2. *Specification of Cantilever Crane actuated hydraulically.*

Total range of lifting machinery 55 feet, allowing the box to be lowered 10 feet below ground level. Number of operations per hour 20.

Diameter of circle swept by cantilever 94 feet.

Lifting speed $4\frac{1}{2}$ feet per second.

Turning speed 6 feet per second at end of cantilever.

Travelling speed 5 feet per second.

Movements.—Lifting and lowering, turning to either side, traversing between minimum rake 21 feet and maximum rake 94 feet; opening and closing the door at bottom of coke box; each movement controlled by a valve actuated by the movement in one direction or the other of a lever in a cabin on the front of the pillar.

High-pressure pumping engine of 20 actual horse-power, having two steam cylinders and two double-acting force pumps, occupying a floor space of 12 by 6 feet.

Accumulator would occupy a space of 11 feet by 11 feet by 38 feet high.

APPENDIX C.

Tensile Strength of Malleable Cast Iron and Manganese Steel Links as used in Conveyors, Elevators, Driving Chains, &c.

1.

Malleable Cast Iron.	Pitch.	Safe working strain per link.
	inches.	lbs.
Ley's bushed chain, pattern No. 604	4	3,000
" " 600	6	2,500
" " 6140	6¼	5,000
" " 7140	6¼	10,000
" " 1200	12	5,000
" " 900	9	13,440

Breaking strain approx. 10 times the safe working strain.

2.

—	Pitch.	Working strain.	Breaking strain.
	inches.	lbs.	tons.
Hunt's patent chain links	4	2,100	9·42
" ordinary patent chain links	6	2,500	10·45
" special " "	6	4,250	18·65
" ordinary " "	12	4,000	16·8
West's special conveyor chain	12	4,000	16·8

The metal of which these links are composed will break at 8·7 to 8·97 tons per sq. inch of section under tensile stress. Tests made at the Whitworth Engineering Laboratory, Owens College.

3. Tests made for Mr. W. J. Jenkins, A.M. Inst. C.E. :—

Ley's bushed chain pattern No. 600, 6-inch pitch. Breaking stress per link, 11·16 tons.

Hadfield's manganese steel of equal sections, 6-inch pitch. Breaking stress per link 23 tons.

Both specimens sheared at the pins.

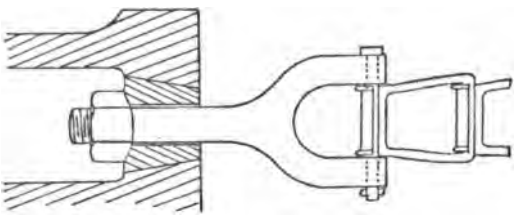
4. Tests made by Mr. Thomas Nash, of the Sheffield Testing Co., upon links made of malleable cast iron, and similar links made of Hadfield's manganese cast steel. (See the Tables on the two following pages.)

10,285 *8th Aug.* 1894.

Manganese Steel.—A Tensile Test of Eight Links of a Conveyor Chain.

Received from Messrs. Hadfield's Steel Foundry Company, Limited, Sheffield.

Sketch showing Method of Testing adopted.



Ball and Socket Holder.

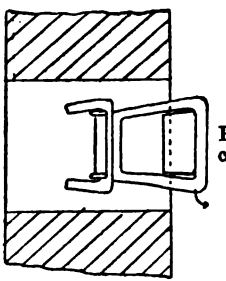
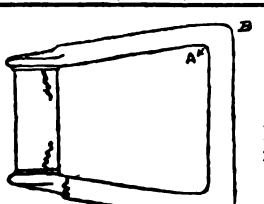


Plate bearing against cross-head of machine.

RESULTS.

Test No.	Description.	Distance between Gauge Points.	Load in Lbs. Deflection and Set in Inches.															Limit of Elasticity.		Breaking Load.		Total Extn.
				500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	7000	8000					
		inches																lbs.	tons	lbs.	tons	inches
2668E	Eight (4″ centres) links of conveyor chain	29	Extn.	0	·03	·06	·08	·10	·12	·14	·16	·18	·22	·25	·30	·46	·79	5000	2·23	8160	3·64	1·40
			Set			·02			·02				·10		·18							

Position and appearance of the fracture.



Dotted lines show position of fracture.

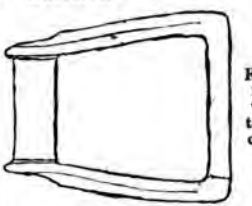
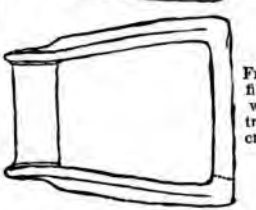
One of the other links had a slight crack at the position marked A, and the part marked B C was in each case curved after the test. Fracture finely granular, with a slight trace of foreign matter.

(Signed) THOS. NASH.
Sheffield Testing Co.

10,333 — 17th Aug. 1894.

Tensile Tests of Two Malleable Iron Conveyor Links.

Received from Messrs. Hadfield's Steel Foundry Co., Limited, Sheffield.

Test No.	Mark on Specimen.	Description.	Position of Gauge Points.	Load in Lbs. Deformation of Link and Set in Inches.									Breaking Load.		Remarks.
					500	2000	3000	4000	5000	6000	7000	7500	lbs.	tons.	
2798E	H	Malleable iron conveyor link in series with five manganese steel links (all 4-in. centres), the malleable being one of the two centre links.		Defm.	0	·02	·02	·04	·08	·13	·20	·25	7640	3·41	Dotted lines show position of fractures.  Fracture fibrous with a trace of crystal.
				Set		0		·03							
2799E	P	Malleable iron conveyor link in series with four manganese steel links (all 4-in. centres), the malleable being the centre link.		Defm.	0	·02	·03	·04	·06	·10			6310	2·82	 Fracture fibrous with a trace of crystal.
				Set		0		·02							
															After the tests, the manganese steel links, although slightly bent at the pin end of the links, were still in good condition.

(Tested links returned.)

(*Signed*) THOS. NASH.
Sheffield Testing Co.

APPENDIX D.

A bottle of about 280 cubic inches capacity was taken and its weight noted; call this weight A. The bottle was then filled with water; this net weight is called B; then filled with coke, and net weight called C; then the interstices of the coke were filled with water, and this net weight noted as D.

The apparent specific gravity was taken as $\frac{C}{B}$.

The real specific gravity was taken as $\frac{C}{B - (D - C)}$.

—	Authority.	
	—	Rankine.
Specific gravity of water	1·000	
" Welsh coal	1·313	
" anthracite	..	1·602
" Newcastle coal	1·256	
" Derbyshire and Yorkshire	1·292	
" Lancashire	1·273	
" Scotch	1·260	
" bituminous coal	..	1·24–1·44
" shale	2·3	2·6
" felspar	..	2·6
" coke	..	1·0–1·66

DISCUSSION.

Mr. G. E. Stevenson (Manchester): Mr. President, I have very great pleasure in responding to your invitation to speak on this question. Mr. Holgate's paper is certainly most thorough and complete, and embraces the whole subject of coke-conveying plant. He must have spent a considerable amount of labour in its compilation, and that we are much indebted to him for giving us such a mass of information, which we could only have obtained with difficulty and a considerable amount of labour in any other form. The coke-conveying plant in use at the Gaythorne Works at Manchester is in connection with an installation of inclined retorts, and it was somewhat of

an experiment when we decided to have it, because, as you are aware, up to that time there had not been any mechanical conveyor of coke applied to inclined retorts. I was somewhat doubtful whether we should not find a difficulty in dealing with a large quantity of coke falling out of an inclined retort at once, the conditions being somewhat different to those of horizontal retorts, where a small portion of coke only is drawn at a time. But no difficulties have been experienced with that matter at all. The coke conveyor is of such ample capacity for the coke it has to take away, that there is no crowding or overloading, or congestion, and, mechanically, the conveyor works exceedingly well. The trough conveyor, I consider a very great success, and there has been nothing in the way of weakness or defect about it from the beginning to the end. The other portions of the arrangement, especially that portion known as the "plate" conveyor, which conveys the coke overhead to the coke heap has, perhaps, not been so satisfactory from all points of view, and I am not inclined in the future to have anything to do with plate conveyors, if they can possibly be done without. The drag conveyor is, I think, far the better thing; there is not the slightest fear of the coke being broken up by being dragged along in front of the retort bench. The coke falls out of the inclined retort all at once, if it is properly carbonised in properly heated retorts. It assumes the form of an oblong heap in the trough, covering the chains and the links and everything, and travelling along in that form without being in the least disturbed or losing its form until it comes to the shoot falling into the elevator. The elevator is like other elevators, except that the buckets are placed very close together, so close that no coke can fall between them, and the shoot which directs the coke into the elevator is so constructed that its mouth is exactly over the bucket as it comes up, and the mouth being the same size as the bucket itself nothing drops into the pit below. So, mechanically, we may say the thing is a success. As to the shaking screen, that is also a success and very useful. The sole purpose for which it was placed there was to take out the dust and small stuff. It was not intended at all to sort the coke. With regard to the saving effected by conveyors, I was particularly struck by the statement in Mr. Holgate's paper that the cost of labour in hauling coke was as much as 4·3*d.* per ton. I am afraid in those cases there has

been very little saving effected at all, because there is no difficulty in wheeling coke from the retort house and depositing it in the yard at something like that cost. We find in our case at Manchester, we save roughly something like 4⅔*d.* by doing away with the coke wheelers. Twelve wheelers have been dispensed with by the machinery, and in their place there is one man to attend to it. As regards capital cost our installation at Gaythorne came to 2440*l.*, everything included, and that works out in this way, at a cost of 11*l.* 5*s.* 9*d.* per double mouthpiece of a retort bench; but naturally, that rate of cost would be diminished if there was a longer line of retorts, because the outside portion would be the same, whatever the length of the retorts, it would only mean a longer trough, so I think the estimate I gave last year in my presidential address may be taken as fairly accurate, viz. about 10*l.* per mouthpiece. The wages saved are 17*l.* 10*s.* per week on 900 tons of coal, making, as I have already said, a saving of 4⅔*d.* per ton. That in a year would be equal to about 500*l.*, at 200 days' working, so the saving in wages would be equal to about 20 per cent. on the capital cost of the plant.

Mr. Foulis (Glasgow): What is the wear and tear?

Mr. Stevenson: It is not possible to say anything definite about that at present, because the machinery has been at work so short a time, only three months at the most; but from what I can see I do not think it will be excessive. There have been no breakdowns, with the exception of a link of a driving chain having given way once or twice; and I do not think the wear and tear in the trough can be rapid. The trough has already become smooth through the scraping of the coke, and as it becomes smooth the friction decreases. Mr. Woodward's scheme, to which reference has been made in the paper, is for a circular gantry with a crane going round attached to a centre-pin. That is going to be put up at the Bradford Road Works. It is a very simple method of stacking coke, but the coke has to be brought to it first of all before it can be dealt with by the crane. I do not myself expect any great saving in labour from that arrangement; but I think it will prevent the crushing of the coke, and its deterioration and disintegration to such a great extent as takes place at the present time, when we are bringing the coke up the heap on rails, which is very destructive.

Mr. E. A. Harman (Huddersfield): May I enquire what is the

quantity of coal carbonised per annum at the Gaythorne Works. Mr. Stevenson has given us some useful figures as to the work there, but the quantity of coal carbonised is omitted. I notice on page 45 Mr. Holgate says, "Pan or plate conveyors, however suitable for dealing with coal, are not so for hot coke." That is, in my judgment, a debateable point. Having used one of these pan conveyors for a considerable time without difficulty of any kind, I am prepared to question the correctness of that statement. My own opinion is that pan conveyors made of suitable metal are quite as available for dealing with hot coke as for dealing with coal.

Mr. STEVENSON: Nine hundred tons per week is the quantity of coal carbonised in this installation at the Gaythorne Works. That is not the whole of the work done at Gaythorne, but the whole of the work done with the conveyor and inclined retorts.

Mr. P. H. FLETCHER (Evesham): I should like to ask Mr. Holgate which form of conveyor brings the most useful coke into the yard—that is, the conveyor which carries the coke, or that which drags it along. I should imagine that the conveyor which drags the coke reduces it to a much smaller state than that which carries it.

Mr. T. GLOVER (West Bromwich): I have been following this question for some time with great interest, and at the present time my committee have under consideration the question of putting in an installation of machinery for the purpose of hauling and storing coke. When I took charge of the West Bromwich works, the coke was drawn on to the floor, and wheeled into the yard in wooden barrows. According to the standard rate of wages in South Staffordshire, the cost of doing that was 8¼*d.* per ton, and loading into the boats cost 4¼*d.* per ton, so that the total labour charges of removing the coke amounted to 1*s.* 0½*d.* per ton of coke. A short time ago we introduced steel barrows of a special design, and that brought down the cost of removing and loading to 11*d.* per ton. We are not content with this figure. We still believe that the labour charges in handling the coke are far too high, and we are at present considering the installation of a conveyor of the best type we can find. Working out the cost on an assumed capital charge of 2½*d.* per ton of coke, the labour charges at 2½*d.*, and the power for driving at 1¾*d.*, the saving would come to

5¼*d.* per ton, and on an annual production of 15,000 tons of coke the saving would be 323*l.* Those figures will show that the matter is well worth the consideration of all who have got works carbonising, say, from 20,000 to 30,000 tons of coal per annum. There is no question that the cost of handling coke in a gas-works is much too high, and that we are now on the way, by means of stacking machinery and conveyors, of reducing it to a much more moderate figure.

Mr. J. West (Manchester): I did not intend to say anything on coke conveying, but I am sure we must all be pleased that Mr. Holgate has laid such a mass of matter before us. He has gone into the matter most thoroughly. I, for one, have been acquainted with the advantages of machinery and mechanical conveyors for a very long time; and speaking on the principle generally (because it would hardly do for me to select any special plant), I think I may say that we are all agreed that the adoption of mechanical conveyors for coke and coal is a very important matter. I could give a number of facts and figures to show that the saving at various works has come out at considerably more than was anticipated, especially when the conveyors were adopted on a large scale. Mr. Holgate has put it very fairly, and there is no doubt that, in comparison with other schemes, the conveyor scheme is the most economical, and will prove itself to be one which will eventually be generally adopted. I should like to say one word as to the conveyor at Gaythorne Gas Works, Manchester. My firm had the opportunity of doing something special there for Mr. Stevenson, and I can assure you that the result has come out beyond our most sanguine expectations. The whole plant works smoothly and nicely. I think a question was put by Mr. Foulis as to the wear and tear. There is no doubt that is a very important factor. For many years we struggled against this question of wear and tear in coke conveying. We found coke conveying was a very different thing from coal conveying as regards the wear and tear of the mechanism. Many minds have been brought to bear on this, and speaking generally the makers have met that difficulty, and the wear and tear is reduced very considerably by the adoption of proper materials applied in a proper manner. It will never come so low as coal conveying, because coal sometimes assists in lubricating the parts, whereas coke acts like emery on the walls of the conveyor. Speaking generally of coke conveying,

I should say it is worthy of every gas engineer's consideration, and the sooner he adopts it, the sooner will he find the cost of manipulating coke in a gas-works reduced.

Mr. S. GLOVER (St. Helen's): I think there is one point about coke conveying that has been missed. Not only is it important, in reducing the cost of handling the coke, but it becomes absolutely necessary to have some means of removing the coke quickly from inclined retorts. How the coke from these retorts is going to be removed as quickly as it can be discharged without some form of conveyor I do not know. I cannot see how it could be done by barrows; therefore it becomes almost necessary to have some form of conveyor. I should like to ask Mr. Holgate whether he had an opportunity of seeing the De Brouwer conveyor at work when the Institution visited the Continent, but it seems to me very unlikely that a round crossbar, acting with two side chains, would have sufficient grip on the coke to push it along such an incline as that shown on the diagrams. Perhaps the President will give us his experience on that matter. Mr. West, speaking of the simplicity of the conveyor adopted at Manchester, failed to mention one important feature of it, in addition to the fact that it does not show much wear and tear, viz. that the part which is most susceptible to wear and tear is the most susceptible to renewal. Though the diagrams showing the Manchester conveyor do not show any elevating of the coke, yet I am convinced that if the conveyor with a crossbar will convey coke at an angle, this one will convey it more perfectly. Having seen the conveyor in operation, I am convinced that coke conveying is much more possible than it has ever been before, and without that destruction of the coke of which there is a fear in the minds of some Members. The uneven shape of the pieces of coke assist the mass to travel without any rolling motion, whereas one would have expected that the pieces of coke would have become like pebbles. Not only is the coke pushed along, but with it the fine dust from the floor, and also the water in front, doing the work of slacking the coke. With regard to Mr. Holgate's remarks as to coke washing, I think he has failed to make his paper perfectly complete, by not describing the coke handling plant in operation at the works of the Corporation of Nottingham, under the charge of Mr. Chester, where coke-handling plant has been in thorough and efficient work for some years, dealing

with coke of different sizes and washing, and preparing it for the market. There is one remark in Mr. Holgate's paper, on page 53, dealing with the analysis of coke from retorts charged by West's manual machine; but the analysis depends entirely upon the quality of the coal and its different properties. Therefore it is of very little value except for one particular form of coal which he might have been using at the time.

Mr. B. W. SMITH (Smethwick): It was rather in view of the great demand made during the last winter for an increase of wages that my Committee decided to put in a coke-handling plant. This plant has not been fixed at present, but I anticipate that we shall save from 5½*d.* to 6*d.* per ton in handling coke into boats or into the stacking ground. The remarks which have been made I can fully agree with, also that it becomes day by day more important, for both large and small works, to put down coke-handling plant to save the expense, besides the great worry and anxiety in the winter of dealing with the coke, and contending with the strikes and irregularities of the men. I do not think there is anything which gives so much trouble in the winter as dealing with coke by the coke barrows.

Mr. C. E. BOTLEY (Hastings): I have been looking into the question very much with a view of devising some means for coke conveying, but at present I have not come to a conclusion as to whether in the new works we are about to build some system of taking the coke from the vaults by means of wire haulage would not be more economical than putting up conveyors. The difficulty I am in is that of a good many other gentlemen, viz. one of wear and tear. The information given to-day seems to show that this has been overcome to a great extent, and, if that is so, it will probably lead to an extension of the system of conveying coke in a similar manner to that in which coal has been conveyed.

The PRESIDENT: Personally, I have not hitherto been in favour of mechanical coke-conveyors, because I think that the wear and tear, in spite of all we have heard to the contrary, must be very heavy. The reason for that wear and tear is the quenching of the coke on the conveyor itself. It does not matter how simply or how well the conveyor is made: but if you allow it to get hot from any degree of heat up to red heat and then put water on it for quenching purposes you must ruin the conveyor. The life of a conveyor therefore depends

entirely on the way the coke is quenched. During the past five years I have seen many conveyors of every description, and the only one which, in my opinion, fulfils all we require is the De Brouwer conveyor. The conveyor works in water; and it seems to be a *sine quâ non* that the coke has to be quenched as soon as ever it touches the fabric of the conveyor. There is, however, a drawback to that, because it involves quenching in the retort house under the noses of the men. Our men in Denmark are not generally very particular, but they object very strongly to have the coal quenched under their noses. They said they were being choked and stifled, and demanded, in consequence, more wages. I think, in using a coke conveyor, you should make every possible endeavour to quench the coke outside the building, but then you get the conveyor very hot, so you are labouring under two difficulties; either you have to quench the coke as it goes on to the conveyor and so choke the men, or to quench the coke outside the retort house and spoil the conveyor. I tried, in designing the Fredericksburg Works, to do away with the use of the coke conveyor by a system of wagons, made on the American Hunt principle, to open and discharge their loads. These wagons were made of strips of steel; they were filled, lifted by a hydraulic lift and allowed to run along the railway to the end of the retort-house. But so great was the heat that the wagons became almost red-hot, and when we sought to apply the quenching process, twisted and warped in every possible direction; and for every man whose labour we saved in the retort-house we had two smiths at work outside repairing damages. Then we had the wagons on a switchback railway; but in working out the incline we had underestimated the wind force, which, when behind the trucks speeded them beyond control, so that every morning the manager had a truck either in his conservatory or in his fowl-house. In fact, he became so accustomed to it that it did not even waken him. In this case I do record a failure; and I wish many members would tell us of these failures, because we learn more than we do of success from them. I am now building in Copenhagen a large retort-house, which is to be fitted with a De Brouwer conveyor, and I hope to solve the question whether that conveyor can deal with inclined retorts. If you come over to Copenhagen in the Autumn, I hope to be able to show you a very fine house fitted with such a conveyor at

work. Personally, I have to thank Mr. Holgate for very much that is given in his paper. In many cases, papers of this description partake of the nature of a specification, but, although they may not be palatable reading, yet they will form a very valuable guide when we go home and are called upon to construct coke conveyors ourselves.

Mr. T. HOLGATE (Halifax): Mr. President and gentlemen, I find some little difficulty in replying to a few of the remarks in the discussion, because the figures given by the speakers as to cost in some cases refer to the cost per ton of coal carbonised, whereas, in other cases they appear to refer to cost per ton of coke handled. Taking first the cost at the Gaythorne Works at Manchester. Mr. Stevenson tells us 900 tons of coal were carbonised in a week, and the saving due to the coke conveyor, elevator, &c., was 17*l.* 10*s.*

Mr. STEVENSON: I said we saved 17*l.* 10*s.*

Mr. HOLGATE: I understand the explanation of the saving was 17*l.* 10*s.*, which works out at $4\frac{2}{3}$ of a penny per ton of coal carbonised, as compared with the cost of hand labour. I should expect the saving to be greater at Gaythorne Works than with a rope-haulage arrangement, and I pointed that out in my paper. If Mr. Harman could have given us some idea of the details of the hot-coke pan conveyor which had answered satisfactorily, it would, I think, have added to the value of his remarks. In my enquiries I have watched these heated conveyors at work, and I have come to the conclusion that the amount of wear and tear which comes on that form of conveyor is very serious. With reference to the remarks of Mr. Glover, of St. Helen's, as to the information given in the paper respecting the proportion of coke of various sizes, I have to say, although the information may not perhaps be very valuable to him, it has been serviceable to ourselves, and perhaps a plain statement of an actual fact may have some merit in it. The President has given us a good lesson this morning upon the advantages of scientific enquiry, and Professor Clerk-Maxwell when asked to define what scientific research was, said it could be summarised in the word "measurement"—that word being taken to be a definite statement of some fact. I think that plain statement, with reference to the screen, will have some value. Mr. Glover also expressed his dissatisfaction that no reference was made to the work done at Nottingham. I understand that Mr. Chester

is preparing a paper on the coke-handling plant at Nottingham (expected to be read next month), in which he will deal with what has been done there. With reference to the ability of the De Brouwer conveyor to lift coke at an angle of 30°, I can only say I have had no actual experience; I have not seen it done. At the Hague Works the conveyor was simply moving the coke along a level surface; but I am told by those who have gone into the matter carefully that an angle of 30° can easily be surmounted by this form of conveyor. If difficulty existed, there is no reason why the crossbar should not be changed for some form of scraper, which would enable the coke to be taken up at the angle of 30°, or at one still more steep. I omitted to state that there is in the room an illustration of a coke-conveying plant in use at the Wellingborough Works. Mr. Lewis, the engineer of those works is present, and I mention it as an instance of a coke-conveying plant for a small gas-works. We all appreciated the remarks of the President, but it has occurred to me that perhaps the quenching of the coke in the retort-house may not be such a very serious difficulty. We have been accustomed to it in England in the case of ordinary working of the retort-house, and in the case of conveyors I do not think any very serious difficulty will arise in handling the coke in the house.

The PRESIDENT: May I mention that the De Brouwer conveyor will take the coke up at 30°, and does so at many works, and at Copenhagen we are thinking of making the conveyors take the coke up at almost 40°. I do not think that the substitution of a scraper would substantially help the conveyor; the efficiency and simplicity of the apparatus are such, that the bar does the work of a scraper with far less wear and tear; but the amount of wear and tear can only be determined by years of experience.

NOTES ON MODERN SYSTEMS OF RETORT HEATING.

By G. P. LEWIS.

THE several advantages claimed for the use of gaseous fuel in retort settings are now almost universally conceded, and indeed, its employment is absolutely essential to the success of the "inclined" system. It would therefore be only a waste of time to reiterate the many arguments adduced in support of its value for such a purpose.

There is, however, still considerable divergence of opinion in regard to the value of recuperation, the use of steam under generators, &c. The Author has therefore limited this communication to the consideration of such points as form the subject of debate at the present time, with the hope that the suggestions set forth will lead to a useful discussion.

RECUPERATORS.

Classification.—For convenience of comparison, recuperators may be grouped into three classes, according to the degree of recuperation attempted.

Class.	Designation.	Characteristics.	Percentage of Total Heat available in setting, utilised in carbonising.	Chimney Loss.	Relative Figure of Economy.
I.	Simple recuperation	Secondary air heated	58	28	0·84
II.	Double recuperation	Secondary and primary air heated.	68	16	1·00
III.	Simple recuperation, combined with recuperation of carbon.	Secondary air heated and portion of carbon in "waste gases" recuperated.	75	17	1·04

The majority of the recuperative settings constructed in this country belong to Class I., while on the Continent, those possessing the characteristics of Class II. are much more common. A considerable increase of economy is claimed for the latter class, as evidenced by the comparative data given in the annexed table, which has been calculated from particulars supplied by a leading Continental constructor.

The practical application of the recuperation of carbon is at present only in the embryo stage, but those who have made trials of the system under working conditions claim to have achieved complete success. There is no advantage whatever, from a theoretical point of view, in the recuperation of carbon from the carbonic acid in the "waste gases," but it has been found in practice that the redistributive effect on the several heat zones is conducive to economy in working. The success of the system depends on the well-known principle, that the value of any particular method of "setting" or working hangs more upon the *excess of flue temperature* over that in the *retorts*, rather than upon the total quantity of heat available; and also partly to reduced chimney losses. The method of its application to retort heating is illustrated by Figs. 7 and 8. About 20 per cent. of the "waste gases" are returned under the producer, and passed through the incandescent fuel, the result of which is the reduction of the bulk of the CO_2 to CO. This absorbs a considerable amount of heat in the producer, but on the other hand, the gases are drawn in hot, and contain heat about equal to that lost by absorption. The use of steam is absolutely essential, otherwise a very high temperature is engendered above the grate bars.

The system has been applied by Mr. W. J. Jenkins, of Retford, and others, but, as far as the Author is aware, has been limited to combination with "simple" recuperation, although the data available appear to indicate the possibility of greater economy by heating the primary air supply also. The success that has hitherto attended the several trials appears to warrant experiments, on a more extended scale, at the hands of those in a position to make them.

It must be borne in mind, however, that, although settings constructed on the systems classed II. and III. show considerable economy in fuel account, they are not necessarily the most economical from a universal point of view. With "double"

and "carbon" recuperation, considerable extra expense and complication is involved in construction, together with a necessity for greater care in working.

Efficiency.—The arrangements of flues in use at the present time for the purposes of recuperation are many and varied; some possessing great merits, by reason of their combination of simplicity of construction with a high degree of efficiency, while others exhibit a total lack of knowledge (on the part of the designer) of the essence of the recuperative principle.

TABLE SHOWING INFLUENCE OF LOCATION ON THE EFFICIENCY OF RECUPERATORS.*

Type.	Situation of Producer.	Characteristics.	Fig. No.	Percentage of true recuperative efficiency as compared with unit type.	Percentage of total heat in secondary air abstracted from producer and setting.
1	Outside bench	Numerous passages for gases and air supply, with thin division walls.	1	100	..
2	Inside bench	Air flue sandwiched between gas flues.	2	90–95	5–10
3	"	Waste gases flue between air supplies.	3	80–90	10–20
4	"	Waste gas flue sandwiched between side of producer and air flue.	4	75–85	15–25
5	"	Air flue between side of producer and waste gas flue.	5	60–80	20–40
6	"	Air flue by side of producer	6	6	94

The efficiency of recuperators is not only materially influenced by the *character* and *extent* of the passages for the transmission of heat to the incoming air supplies, but also by their *location* in regard to the producers. In fact, in certain forms, the degree of "true" recuperative efficiency attainable is entirely governed by the situation of the flues in relation to the sides of the generator.

* The minimum values of efficiency given are for settings of retorts 10 feet long: also for beds of 20 feet "throughs," with producers on each side.
The maximum values may be taken for 20 feet "throughs," with producers on one side only.

Influence of Location.—The estimation of the real influence of *location* on the true recuperative efficiency, is a somewhat difficult and tedious operation, involving the classification of a mass of data based on observed results. These data should not be confined to figures deduced from any one particular form of recuperator, but ought to be fairly representative of that obtained from all the various types, and systems in use; and in addition, take account of the varying thicknesses of division walls between the gas and air flues. The Author has, therefore, compiled the above table, with the hope that it may be of service, not only as an illustration of the importance of giving due consideration to the question, but also as a handy form of reference for those who may be desirous of estimating the degree of economy likely to be attained by the use of any particular arrangement of recuperative flues. The above table has been calculated from figures chiefly obtained from French and German sources, and is *approximately* correct under *average* conditions.

Some of the figures given in the table may at first sight appear to be rather strained, but a reference to the conditions illustrated on the accompanying diagrams will tend to substantiate their correctness. Taking the type delineated on Fig. 5 by way of an example, it will be observed that in this case the air flue is sandwiched between the side of the producer and the waste gas flue; and proceeding on the assumption that the temperature in the respective flues at the level A A is as follows—

	Waste Gases.	Secondary Air.	Producer.	
	800°	200°	3000° and upwards	

From this it will be seen that the excess of temperature in the producer, over that in the air flue, is 2800° F., while that of the waste gases is only 600° F., or less than one-fourth of the former. Supposing also that the thickness of the producer wall is equal to that of the division tile between the gas and air flues, then the amount of heat abstracted from the producer would be at least four times that from the waste gases in the particular line of flue in question. In practice, however, the

thickness of the generator walls is at the very least one-and-a-half, and in general four times, that of the flue division tiles, while the area of contact, between the producer and recuperator, only occupies a portion of the surface of the latter. The temperatures in the upper portions also practically balance one another; and taken as a whole, more heat is found to be abstracted from the waste gases than from the producer, in this particular type of recuperator.

The lowest type, from the "true recuperative" point of view, is that illustrated by Fig. 6, which abstracts the whole of the heat imparted to the secondary air from the producer and body of the setting; it has no real recuperative action whatever, and owes the small figure of percentage efficiency given in the table to slight reduction in losses, due to radiation from producer. Some engineers advocate the abstraction of heat from the producer in this way, with the idea of moderating the temperatures therein, and adduce arguments in favour of such a course; but at the same time very properly disclaim any attempt at recuperation. In a particular case brought under the Author's observation, the whole quantity of heat in the secondary air at the summit of a similar recuperator was credited as economy due to "regeneration," which was, of course, quite incorrect. The mere fact of air being "heated up" is not of itself any proof whatever of recuperation, but it is nevertheless a fruitful source of error in the estimation of economy.

The use of steam under producers introduces a very disturbing factor in attempts to calculate the efficiency of any particular form of recuperator, as the work thrown upon them is much increased, on account of the additional quantity of secondary air required to be passed through, and proper allowance must be made for this, if even approximately correct data only are required.

Area of Recuperative Surface.—Reliable figures in regard to the extent and character of recuperative surface necessary for the transmission of a certain quantity of heat, at specified differences of temperature, are very difficult to obtain, owing to the disturbing influences mentioned in the preceding section. The Author, however, has been fortunate enough to be furnished with the particulars of the working of two forms of recuperators, hereafter referred to by the letters A and B respectively.

Recuperator A was formed of specially moulded blocks, with passages for air and gases passing through them, while B consisted of channels formed of plain divisional tiles, about 2 inches thick. The results of the two trials are given below, and are most useful in proving that efficient recuperation may be attained by very simple means, and that the recuperator A contained at least double the surface necessary for the abstraction of heat from the waste gases.

—	A.	B.
Area of recuperative surface in square feet per lb. of coke consumed in generator per hour	5	2·62
Difference between mean temperatures of air and gases	752° F.	620° F.
Heat units given up per square foot per hour ..	464	840
Heat units given up per square foot for each degree of difference in mean temperature	0·61	1·35

The main element of success in modern systems of carbonising lies in the practical construction of the setting. This phase of the subject has already been fully dealt with on previous occasions, and therefore it is not considered advisable to lengthen this communication by entering into details under this head, other than to express a preference for the simplest styles of construction, such as that indicated on Figs. 2 and 3. Settings constructed on either of the two systems shown can be constructed at a low capital cost, and are very efficient as recuperators. They also lend themselves excellently well to arrangements of flues which are readily accessible for cleaning and repair.

Use of Steam in Producer Furnaces.*

The advisability of admitting steam under producers is also open to dispute, and, in general, it is much more sparingly used in generators for retort heating, than in similar furnaces employed for metallurgical and manufacturing purposes.

The Author having recently had occasion to investigate the

* In the case of producers with wet ash-pans, the quantities of steam mentioned include that produced by evaporation from the water in the pan, in addition to the external supply.

question, made a series of inquiries in several directions, with a view of ascertaining the quantity of water vapour passed through the fuel by various engineers; but as the external supply is usually obtained from a boiler or boilers generating steam for the whole purposes of the works, the exact weight admitted to the furnaces was not generally readily ascertainable, in every instance. Fortunately, however, in a few cases special methods were employed for producing steam, and measuring the quantity of water evaporated, and consequently the data so obtained could not fail to be reliable. The several figures, when first contrasted, appeared to be incompatible one with the other, but a closer investigation dispelled this view, and indicated the factors governing success, under the conditions prevailing in each individual case.

Action of Steam.—The introduction of steam tends in all cases to reduce the temperatures of producers, but not necessarily the formation of clinker. In proof of this, it may be mentioned that in one particular case in practice (worked on a simple recuperative system), the injection of 20 per cent. of steam raised the zone of maximum temperature about one foot higher in the furnace, and created an arch of clinker about 12 inches above the grate bars, which was much more troublesome than if formed in the ordinary way. On increasing the proportion employed to about 33 per cent., it was observed that the zone of maximum temperature was raised still higher, but reduced in intensity, and was then below that necessary for the fusion of the components of clinker. It was also discovered that reducing the whole supply of steam to well below the figure of 20 per cent. quoted, had a beneficial effect in preventing the formation of an arch of clinker, but did not get rid of the trouble of clinkering altogether, as was the case with the admission of 33 per cent. The results obtained in the particular case under review, therefore, appear to point to the inadvisability of following a medium course, and indicate the importance of avoiding the use of certain proportions. The question of the best percentages to employ is rather a difficult one, under the varying conditions of working, and will be the more readily appreciated, when it is stated that the data in the Author's possession range from 20 to 77 lbs. of steam per 100 lbs. of coke consumed in generators, and that these widely diverging figures were appropriate to the circumstances in which they

were severally employed. With cold primary air, it seems to be advisable to either limit the steam supply to, say, 10 per cent., or increase it to at least 30 per cent. If the primary air is heated, the steam supply must be increased in proportion, approximately as given in table below.

TABLE OF STEAM SUPPLY TO PRODUCERS.

	Per cent. Steam.
Primary air, cold	33
" heated to 400° F.	44
" " 800° J.	60
" " 1100° J.	72

Chemical and Thermal Changes.—The reactions which take place in a producer worked without steam are well known to be exceedingly simple in character; but this is not by any means the case when steam is admitted, as then not only is there an increased variety of primary combinations, but in addition further complex interactions are also produced; and again, the balance of changes so produced is practically reversible, according to the influence of varying temperatures, and quantities of water vapour injected.

As an illustration of the possibility of such reversals being brought about, under the conditions existing in generators, reference need only be made to variations in the reactions between incandescent carbon and water vapour. At temperatures of 1800° F. and upwards, the reaction between carbon and water vapour is practically $C+H_2O=CO+H_2$; but should the intensity fall below the limit given above, and undecomposed steam be also present in excess, carbonic acid is produced, in accordance with the following equations:

$$C+2H_2O=CO+H_2O+H_2=CO_2+H_4,$$

in increasing proportions as the temperature is reduced.

Other important chemical changes are also illustrated on Fig. 11.

There is also a considerable difference in the respective depths at which CO_2 commences to be reduced, between generators worked with, and without steam. In the former class, cases are known in which the carbonic acid has not been reduced at a height of 3 feet above the grate bars; while in the latter, a large percentage of carbonic oxide has been found

in some cases at 12 inches up in the producer. It is, therefore, very necessary to have a deep fuel bed where steam is generously used.

The chemical efficiency of generators is slightly reduced by the use of cold coke, which, as is well known, contains a considerable quantity of water. When the coke is thrown in upon the top of the incandescent fuel, the moisture present in it is driven off into the crown of the furnace, as undecomposed water vapour, which reacts upon the carbonic oxide in the producer gases, in accordance with the following equation:

$$CO + H_2O = CO_2 + H_2,$$

and may also possibly vitiate any analyses of the gases which might be taken near the time of charging.

The dissociation of steam in passing through the incandescent fuel in the producer absorbs, or renders latent, a large quantity of heat, and therefore exercises a most beneficial action in moderating excessive temperatures. It is almost needless to add, that the exact quantity of heat absorbed in decomposing water in the producer is reproduced by combustion in the setting. The temperatures available for heating the retorts should therefore be theoretically constant, whether steam is employed or otherwise. It has, however, been found in practice, that the combustion of the hydrogen (produced by dissociation of water vapour) is much quicker than that of carbonic oxide, and therefore produces a zone of relatively higher intensity, within certain distances of the gas and air nostrils.

It must be borne in mind, however, that a portion of the heat produced by the combustion of hydrogen is rendered latent, and must be discarded in calculations bearing upon the total quantity of caloric available for carbonising; the total quantity of sensible heat units yielded per pound of hydrogen consumed being only 52,000, as against 61,500 when resulting gases are cooled down to such an extent that water vapour is condensed to the liquid form.

Construction of Settings.—Success in the use of steam is also partly dependent upon the construction of the settings. If steam is largely employed where the combustion space is constricted, as shown on Fig. 10, much trouble is caused by the fusion of the retorts and division walls, owing to the very

high local temperatures engendered. The best remedy for the latter trouble seems to be in the use of a roomy combustion space, so that the full energy of the combustion may be utilised, without any drawbacks. The provision of such a space, as opposed to that of an enclosed combustion chamber (irrespective of the use of steam or otherwise) has been proved, in practice, to possess great and undeniable advantages, not only in mitigation of cutting heats on the retorts, but also in the facility it gives for access to every part of the interior of the setting for the purposes of repairs.

Variations in Air Supply.—The respective quantities of primary and secondary air required are governed by the quantity of steam injected; the former being decreased *pro rata* with the weight of water vapour admitted, while the latter is correspondingly increased, the total combined weight being theoretically constant.

The admission of steam, therefore, incidentally affects the work thrown upon the recuperators, as illustrated by the following table, calculated under three suppositional conditions.

	Without Steam.	33 per cent. Steam.	77 per cent. Steam.
Primary air per lb. of coke consumed.. ..	5·5	3·5	2·56
Secondary " "	4·5	6·5	7·44
	10·0	10·0	10·0
Relative work thrown on recuperators ..	1·0	1·44	1·64

The Author ventures to think that, on the whole, the generous use of steam is an advantage, principally on account of the possibility of the reduction of some of the arduous work of clinkering. This statement, however, only extends to its use in setting where the combustion space is ample.

Analysing Waste Gases.—The methods in general use for analysing waste gases are subject to considerable error when applied to gases containing a large percentage of water vapour, such as is produced by the free use of steam under producers. This water vapour, in most cases, is partly condensed out before the gases enter the burettes, and the results obtained represent the composition of the residual gases, after the moisture has been eliminated. Under ordinary circumstances there is no practical disadvantage in this, but it is desirable in experiments involving the generous use of steam, that the real percentages of water vapour present should be ascertained correctly.

It has occurred to the Author on several occasions, that it would be of some advantage to have a means of ascertaining the approximate composition of the waste gases, by mere inspection.

APPENDIX.

Formulæ for Generator Settings.

F = Weight of coke put into generator in lbs.

P^H = " primary air for producer fed with hot coke $= 5 \cdot 3$ to $5 \cdot 8\,F - 3 \cdot 81\phi$

P^C = " do. do. cold coke $= 5 \cdot 0$ to $5 \cdot 5\,F - 3 \cdot 81\phi$

S^H = " secondary do. hot coke $= 10 \cdot 0\,F - P^H$

S^C = " " do. cold " $= 9 \cdot 6\,F - P^C$

$V\,P^H$ = Volume of primary do. hot coke $= 13 \cdot 14\,P^H$

$V\,P^C$ = " " do. cold " $= 13 \cdot 14\,P^C$

$V\,S^H$ = " secondary do. hot coke $= 13 \cdot 14\,S^H$

$V\,S^C$ = " " do. cold " $= 13 \cdot 14\,S^C$

V = " of air $= 13 \cdot 14$ cubic feet per lb. at 62° F.

ϕ = Weight of water or steam injected into producer in lbs.

G^P = " producer gases $= 0 \cdot 83\,F + \phi + (P^C \text{ or } P^H)$.

T' = Temperature of gases leaving producer $= 2800° - \dfrac{2700\,\phi}{F}$.

G^{PV} = volume of producer gases

$$80\,F\,\frac{\left(2800° - \dfrac{2700\,\phi}{F}\right) + 461}{523};$$

or at temperature T'

$$= 80\,F\,\frac{T' + 461}{523};$$

or at temperature 2000° = 367 F.

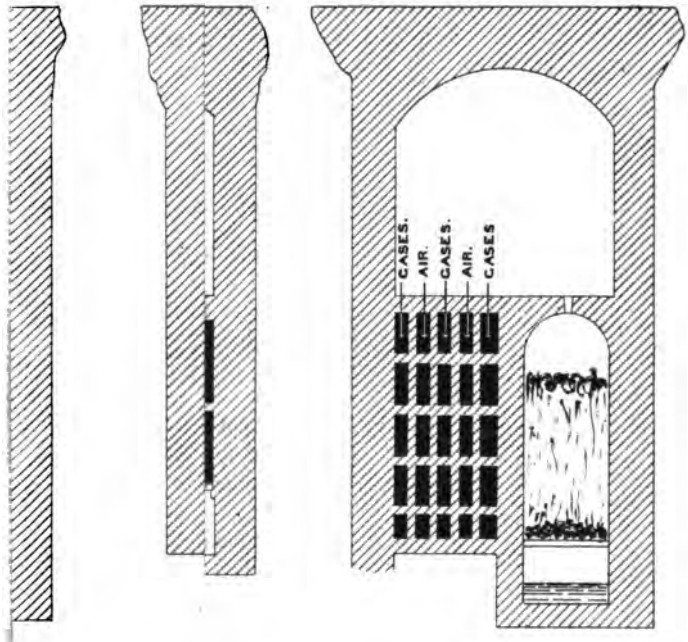
G^S = weight of "waste gases" from setting

$$= 0 \cdot 83\,F + (P^H \text{ or } P^C) + (S^H \text{ or } S^C) + \phi.$$

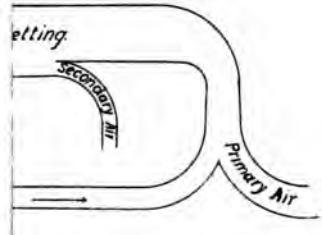
G^{SV} = volume of "waste gases" from setting at temperature T''

$$= 145\,F\,\frac{T'' + 461}{523};$$

or at temperature of 2000° Fahr. = 491 F.



— Fig. 12. —



— Fig. 7. —

— G.P. LEWIS. —

THO. SPRAGUE & Co Ltd 4 & 5, EAST HARDING STREET, FETTER LANE, E.C.

N = area of producer nostrils

$$= 80\,F \frac{\left(2800^\circ - \frac{2700\,\phi}{F}\right) + 461}{150{,}000};$$

where F = fuel in lbs. per hour.

T = theoretical temperature available in setting.

T″ = temperature of gases leaving setting = 0·458 T approximately.

T^{SA} = temperature of secondary air at outlet to recuperator = 0·4 T or 0·88 T″ approximately.

B.T.U. in waste gases

$$= (0{\cdot}83\,F + (P^C \text{ or } P^H) + (S^C \text{ or } S^H) + \phi)\,0{\cdot}458\,T \times 0{\cdot}253;$$

or

$$\frac{G^S \times 0{\cdot}458\,T}{8{\cdot}95}.$$

DISCUSSION.

Mr. Charles Carpenter (London): In obedience to your request I have pleasure in opening the discussion on this paper. I agree with you in your expression of opinion as to its worth to the Members of this Institution. The utility of such papers may be divided under two heads—there is the paper which appeals directly to you, which has the advantage of bringing rapidly before you new notions and ideas, and there is the paper which is of value to you for reference and investigation in the study. I am saying nothing disparaging of Mr. Lewis' paper in expressing the opinion that it falls within the latter category. With regard to the theory put forward by Mr. Lewis I am not certain that I quite follow him. I gather it to be substantially an analysis and summary of the various actions which take place in all recuperative retort settings, and the value that may be obtained by the perfection or otherwise with which the different operations are carried on. We must not lose sight of the fact that to attain this high degree of efficiency requires the expenditure of money, and what we have to consider, from the point of view of money making, and the supply of gas at the lowest figure (which, after all, is what our business is), is

whether the advantages justify the outlay. One diagram on the wall points that out very clearly. That is Fig. 1. I don't gather whether Mr. Lewis holds that out as showing an ideal state of things for a retort-house, whether that arrangement is what he would recommend us to invest our money in, but I am afraid I should be compelled to say of the advantages he would get that I do not think they would be paid for in the money they would return in extra coke sold. With all schemes of recuperation there are two drawbacks which are always with us. One is the large scale upon which gas-making operations in retorts are now extended, and with a delicate piece of mechanism such as that recuperator shown in the diagram, a great deal of attention would be required to maintain the proper balance of heat in the setting. Some time ago in discussing the matter of improvements in recuperation with a gas engineer he told me, with respect to his particular modification, he would not be happy unless he saw his setting three times a day. Well, with a large undertaking it is not possible to work economically with anything which requires the engineer to see it three times a day. Another point is the wear and tear. With retort settings, in which the recuperation is of a similar character to that shown, it is not possible to regulate and control the heats to as great a degree of accuracy as with a simple system of gaseous firing. I have had retorts, the average life of which has been 2500 working days. That is a very long life, and was obtained without any special care apart from the ordinary routine of large works. In that time none of the retorts had to be reset or repaired, otherwise than by stopping up the cracks or holes. In the case of my own company the cost of labour for the repair of retort settings is apparently increasing at a greater rate than that of any of the other repairs; and there is considerable difficulty in getting retort setters and bricklayers to do this work, while they demand a much higher scale of pay than any other mechanics. Therefore it is important that the settings should be put in so as to enable the longest life to be got from them. I notice another diagram, Fig. 10, which shows settings of nines, which with many engineers is a very favourite one. I gather that Mr. Lewis is not in favour of it; and in that case I would very strongly support him in opposition to the arrangement. It is one thing to pack the greatest number of retorts into a setting; but it is

another thing so to regulate combustion as to obtain the greatest duty from the retorts during their life, and the greatest uniformity of heat. I consider that you can do neither in a case where two retorts are sandwiched between two zones of combustion, while the outside retorts have the zone of combustion on one side and the waste gases going away on the other. The result of that would be that the heat of the retorts would be very unequal in those two cases. Some attempt has been made to get over that by shielding; but I think it a very imperfect way of regulating the heat of a retort to make part of it twice as thick as it ought to be. In connection with retort heating I may say we have been trying, for some eighteen months or so, thin retorts, something under two inches thick, and although as they form part of a range of retorts, heated by one furnace, it has not been possible to measure the amount of gas which each setting takes, they have been worked with 30 or 40 per cent. less damper than the retorts on either side. That points to the desirability of getting the retorts as thin as we can, consistent with maintaining their shape throughout their life. I notice another diagram which, I gather, is a cross section. It shows two producers, and I presume it is put forward as the best arrangement of producer for heating an ordinary retort setting. I do not think it is the best arrangement, because in the first case the productive power of the producer is so great it is not necessary to have two of them. Arrangements certainly are necessary for distributing the gas from the producer, and for making the supply uniform, but it is not necessary to have two of them. Mr. Lewis also spoke of the disadvantages of using cold fuel in charging the producer. That depends to a considerable extent upon the arrangement of the producer; and that is one reason why I think the system of making the producer part and parcel of the retort setting is not the right one. The method of converting coke into heating gas should, in my opinion, stand by itself; that is to say, the producer should be designed as an efficient instrument for converting coke into fuel gas, and its design and arrangements should not be bounded by the exigencies of the space between the walls of a setting. The last producers I put in at one of the South Metropolitan stations are 19 feet 6 inches high. The upper part of the producers is arranged as a hopper for cold fuel; and about one-third

of the distance down there is an outlet pipe which goes through from one side of the producer to the other, carrying off the gas to the retort setting. The advantage of that arrangement is that an uniform level of fuel is always maintained in the producer. There is always a layer of fuel above the outlet of the gas which prevents any air being drawn in when the lid of the producer is opened for charging. We find, by analysis of the gas, that the chemical composition is uniform within the limits of the simple tests we use throughout our daily work. The gas is led from the producer to the settings in the same way as we should do if the gas were obtained from another source altogether. My view is that that is the only system by which the greatest advantages will be found in the future. I congratulate Mr. Lewis upon the care and trouble he has taken with his paper.

Mr. Foulis: Will you tell us the size and shape of the producers?

Mr. Carpenter: About 9 feet by 12 feet rectangular.

Mr. G. Helps (Nuneaton): I should like to ask Mr. Lewis whether, when he speaks of the relative values of recuperators, the recuperators he used to obtain the different values assigned to them in the table, were the same in each case. The value of a recuperator depends largely on the soundness of the secondary air flues. My experience with regenerators of all kinds has been that nearly always the flues or passages for the gases were not sound; and it was quite possible that if different settings were employed to arrive at the values given in the table, the soundness of the flues might have varied in the different instances—which would affect the test. Again I should like to ask if the producers, or the recuperators, were connected with similar settings in each case, as my experience has been that the setting itself has a very material influence on the amount of fuel used. It appears from the table that double recuperation is better than simple. I was of that opinion, until six months ago, when I fixed up a recuperative setting, having about six tiers of flues or passages, three being arranged for heating the secondary, and three for heating the primary air, but so arranged, that the heated primary air could be shut off, and cold primary air used at will. The primary air was heated up to about 1500 degrees. After working the setting some time with the heated primary air, it (the heated air) was shut

off and cold primary air used. I failed to discover any difference in the fuel consumption, in favour of heated primary air. In each case the heats had been good, and the retorts charged with 3 cwt. of coal every four hours. The fuel account was low.

Mr. G. E. STEVENSON: I have been much interested in this subject from the time it came up at our meetings; and I must say I have been struck with one thing, that there seems to be a marked division line between the two classes of opinion respecting this method of heating. There are those who think that gaseous firing in itself is the great source of economy, and when once you have got gaseous firing, and got that to heat your retort, you have done all that is well worth doing. There are others amongst us who think that the application of the recuperative principle—the abstraction of the heat from the waste gases and the utilisation of this heat again by communicating it to the air supply is of equal importance. I must say I belong to this latter class. I quite see and appreciate the value of gaseous firing; but I believe in thorough recuperation also.

The PRESIDENT: What do you mean by thorough recuperation?

Mr. STEVENSON: I mean the abstraction of as much as possible of the heat contained in the waste gases, and its reintroduction into the setting. I was going to say that I do not think it very much matters as far as the question of economy of fuel is concerned, what proportion of that heat is admitted through the primary or what proportion through the secondary air, but I think it is possible to go to excess in the heating of the primary air. When I hear of such figures as 1100° and 1500° applied to the primary air I want to know what fire-bars will stand that heat. What will be the condition of the fire grate after a day's working? It is quite true that the waste gases contain practically double the volume of heat you can put into one of those divisions of the air supply—a great deal more heat than you can put into the secondary air supply; and what you cannot put into the secondary air you may as well endeavour to utilise in heating the primary air. But I think most of us who have gone in for regenerative furnaces, have first endeavoured to heat the secondary air to such a point as was practicable, and then utilise the waste heat for the primary air,

and by this means you get a high state of efficiency. When the waste gases are down to such a temperature that the main flue shows no colour—is practically black—I think you have not done so very badly in the way of recuperation; in fact, you can do no more. There must be sufficient heat in the waste gases to create a draught. With a setting built for inclined retorts you have got to make your draught sufficient to pull the gases up 20 feet high, and then down again 20 feet. That wants considerable difference of temperature, or otherwise how are you to get the draught? I think all these discussions on furnaces and regenerative heating are of very great value, because there is always something elucidated, something fresh we have not observed before. The question Mr. Lewis has brought forward as to the quantity of steam you can use under the fire grates is very useful. I do not use steam myself; I use water trickling over plates, which I think is quite sufficient, but I know there are others who find steam useful. There is no doubt by the use of steam you transfer the zone of intensest combustion further up into the furnace; and according as you construct your settings with that object in view, or otherwise, you gain a useful advantage. I prefer to have a pretty intense temperature in the lower zone. I believe you do not get your carbonic acid reduced properly and fully to carbonic oxide, unless you have a fairly high temperature in the lower part of the producer. Each of us must have our own ideas on the subject and must endeavour to work them out on our own lines.

Mr. Holgate: I should like to ask the Author of the paper upon what supposition he bases the statement in class 3 on page 82, "secondary air heated and a portion of carbon in waste gases recuperated"? What proportion of the waste gases are supposed to be treated there? Is this statement based upon the treatment of say 50 per cent. of the waste gases, or is it based upon some other figure?

Mr. Lewis (Sydenham): I can hardly recollect now, but I think it is based upon 20 per cent.

Mr. Holgate: I daresay it will be within the recollection of many Members that a few years ago, Mr. Head, who represented Messrs. Siemens, brought to the notice of gas engineers a method of utilising waste gases by passing 50 per cent. of them underneath the grate of the producer for the purpose of reducing the carbonic acid to carbon monoxide; a method

which has been followed out in connection with steel heating furnaces with good results. I had occasion to reconstruct some settings with regenerative furnaces, and I placed them at the disposal of Mr. Head to see what could be done by the utilisation of the waste gases. The furnaces and recuperative flues were so arranged that they could be worked in the ordinary fashion or a portion of the waste gases could be put under the grate. But there a difficulty arose. Theoretically, 50 per cent. was required, but the quantity sent under the grate had to be regulated by a steam jet, which proved very erratic. The quantity sent in would vary with the steam pressure. Then again the temperature of the waste gases after passing through the whole length of the recuperator was not sufficiently high to become of use in the producer. The conditions which operated were very different from those which operated in the case of the steel heating furnaces. In that case the waste gases came at a very high temperature, straight into the furnace, and I think those conditions quite explain why Mr. Head was not able to make his trial a success. Of course theoretically it would be an advantage if some portion of the waste gases could be taken before being cooled in the recuperator and passed under the grate; but then, again, comes the question whether, after all, that is the best method, even theoretically. There has been passing through my mind an idea which may perhaps have been put to the proof by some of the members, and if so, I should like to hear the result. You will remember, in days gone by, Mr. Croll, at the Great Central Company's works, arranged to have underneath the ordinary clay retorts a number of iron retorts where the heat from the clay retorts could be utilised. To this extent these iron retorts were recuperators. Now that we have gaseous fuel it has occurred to me, is it possible to have a large producer, as Mr. Carpenter has suggested, introduce the whole of the gas made in it into the first setting, admitting into the setting just the necessary amount of air to cause the combustion of a part of the producer gas sufficient to give heat in the setting, then pass the whole of the waste gas from that setting into the next, and admit another supply of air, and so on, in succession, allowing in each successive setting the amount of air required to raise the temperature of the gases to the carbonising temperature. You then make the retorts into recuperators; simply raising step by step, the

temperature of the gases by the admission of the proper quantity of air as the process proceeds. After a certain limit has been reached, you will be able to pass the waste gases through an ordinary recuperator, and in that way supply the settings with heated air.

Mr. FOULIS: This is a very old subject with me, for I think I was about the first to introduce these settings into this country. There is one remark in this paper I do not quite understand, and that is about the temperatures. Mr. Lewis says the excess of temperature in the producer over that in the air flue is 2800°, while the waste gases are only 600°, or less than one-fourth of the former; I do not exactly understand what that refers to. There are just two other matters I would like to mention, first as to the equal heating of retort settings. In order to insure equal heating it is essential that the air and gases are brought together in such a way that there is no blowpipe flames but a gradual consumption all through the setting. If that is done there is no difficulty in maintaining equal heats from top to bottom. I may say I quite agree with what Mr. Carpenter has said, that the method of heating retorts in the future will be by having large producers altogether separate from and outside the retort-house, where gas not only for heating the retorts but for all other purposes of heating in the works, will be produced and carried by flues to the various points where it is wanted. I have also been experimenting in this direction, and during last winter we had sixteen settings of twelve retorts each, heated in this way, with a very considerable amount of success. The experiment is not quite so satisfactory as I should have liked; but we are now making certain alterations which I think will make it quite successful. I am strongly of opinion that is the method which will be adopted in the near future, at all events for large works.

Mr. FLETCHER: I should like to ask Mr. Lewis why steam has the effect of causing a cutting action in the setting. It seems to me when you have a gas fired setting, no cutting action should take place. There should be no draught in a setting of that kind which should be likely to cause a cutting action. Fig. 10 does not appear to represent what is actually taking place in a setting of that kind. I do not see why you should expect to get a more even heat in such a setting. There would be more heat in the middle of the retort than on the outside, as

there would equally be in Figs. 4 and 5, but I think that the amount of heat in between would greatly depend on the draught. If the gas is pulled through the setting it has a tendency to make a blow-pipe flame, but if you do not work with more draught than is necessary, the setting will probably be under pressure; I think the most economical mode of working will be found when a pressure exists low down in the setting. In that case I do not think the flame will be like a blow-pipe, because it could be extended right down into the waste-gas flue, where recuperation is going on. It shows that the flame is not a short flame, and I take it that it is the same as the blow-pipe, as you increase the air and the pressure the flame is decreased in length. I do not think if the settings are worked with sufficient draught, but not too much, that the settings in Fig. 10 will be found far below those in Figs. 4 and 5. As far as an outside producer goes there may be many points in its favour; it may be more scientific, and a better result obtained, but the question of the cost of erection must be considered. I think it will be much more costly than an ordinary setting with a producer underneath, but I do not think that the fuel account will be any better.

Mr. HARMAN: I should like to call Mr. Lewis's attention to the first paragraph in his paper, "The several advantages claimed for the use of gaseous fuel in retort settings are now almost universally conceded, and indeed, its employment is absolutely essential to the success of the inclined system. It would, therefore, be only a waste of time to reiterate the many arguments adduced in support of its value for such a purpose." I should like to ask what special features he had in his mind in framing that paragraph—what he specially alludes to in the setting for an inclined system as being different from a setting for the horizontal one.

Mr. T. S. LACEY (Pimlico): With regard to the blow-pipe flames shown on Fig. 10, I had a case where a setting of retorts was rapidly destroyed by being heated up by flames of that character. There was a very large excess of secondary air, the dampers had not been adjusted quite rapidly enough, and the combustion which was produced was so very excessive, that it destroyed the setting.

The PRESIDENT: This subject almost amounts to a hobby with me; I do not quite see the drift of Mr. Lewis' paper. He

seems to be a special pleader for the use of steam under retort settings. It seems to me the use of steam under retort settings is utterly unnecessary, because you can, in a properly constructed regenerator setting, always have sufficiently hot waste gases coming away to produce steam in the water-box under the fire-bars. Beyond this I do not see that the use of steam plays any important part in the setting itself. Many people, on the continent, I believe, have tried steam injection; and they have given it up. We have ten gas-works and ten managers, and they have all tried different experiments with and without steam, and they have come to the conclusion that steam is not of much use. When we first tried the regenerative system we admitted so much secondary air and cooled the furnace gases so low that we could not get sufficient heat under the fires; and then we had recourse to steam for a short time. But when we rebuilt the settings we took care to make the flues so as to get sufficient heat under the last channel, where there is a water box. At Vauxhall, many years ago, when we started a regenerator setting there, a Klönne setting, which was one of the first put up in England, it was absolutely necessary to use steam. But all that is needed, in order to keep the fires clear, is to have the zone of combustion at the proper place in the regenerator. Therefore, I fail to see altogether the use of steam for regenerator settings. Then there is the question of heating up the primary air. We tried that also, and gave it up; we made many experiments, but found no results worth obtaining by heating the primary air, because it has to be heated up at the expense of something else; and it is far better, if you wish to heat air at all, to heat secondary air; I believe it is a waste of time and money to endeavour to heat up the primary air; and my view is fully borne out by Mr. Holgate's statement. I daresay some of you read the gas journals, and some eighteen months ago you may have seen the controversy between myself and Mr. Carpenter. Mr. Carpenter thought that the generator should be outside the setting, while I had a firm belief that it should be inside. The reasons for my belief are these: that I may store the radiated heat. Mr. Carpenter's reasons are that there should always be a superincumbent weight of fuel over the exit of your gas—and he is quite correct and I thoroughly appreciate it. Speaking with my manager the other day, we came to the

conclusion that if we were to build any more settings we would sacrifice the principle of saving the heat, in order to gain what Mr. Carpenter wishes to gain by taking the gases away from a lower zone in the generator. When one has made a mistake, or feels that other people know better, it is well to acknowledge it. I do not give in to Mr. Carpenter entirely in this matter. I do not believe we are going to have one generator, and take the gases away to any portion of the retort-house; but I am thoroughly with him that you must take the gases from the generator at a level where, on opening the generator, you do not get a blast of cold air into your settings. It does not matter how nicely the flues are adjusted, or what appliances there are for controlling the secondary or primary air inlet; if you are continually lifting the feeding door off the top of the regenerator for filling purposes you upset the equilibrium of the setting for two hours afterwards. I took enormous pains and had a chemist continually analysing the furnace gases and the waste gases in the main flue; as you cannot properly control your primary or secondary air unless you do that. The amount of air drawn up the main shaft is varying a thousand times a day, it is never constant; and the result is to continually alter the equilibrium of the furnace. Therefore, if you wish to arrive at perfection, you must have an automatic regulator on the inside of your flues. But, of course, that is almost too theoretical. We tried to meet the difficulty in this way: by having on the inlet of the primary air a suspended flap. It is a German invention, so that as the draught in the chimney increases, this automatic flap closes to a certain extent, in order to allow, what we believe to be, the theoretical amount of primary air to enter. We do not care much about the secondary air, because a little more or less, does not play any very great part in the economy of the setting; but the primary air has to be apportioned absolutely to the chemical requirements of the generator. The secondary air will, to some extent, take care of itself; but if you wish to get thorough results from a setting you must study the primary air. Many people, instead of letting it go under the bars direct, make the primary air take a sinuous course through the side of the setting and then underneath the bars. That is a good idea, because the sinuous passage is not subject to blasts of cold air through the retort-house, which are experienced when the primary air is admitted

immediately under the bars of the furnace. We have now furnaces in which we have brought down the consumption of coke to from 10 to 12 lbs. per 100 lbs. of coal carbonised. There are two gentlemen present, the managers of the Fredericksberg and Flensburg Works, who will be pleased to show the accounts they return to me at the end of every half year. The accounts of the manager of the Flensburg Works are at present the best, showing 10 lbs. of coke per 100 lbs. of coal carbonised. Then there is another matter—that is the cost of the bricklaying—which Mr. Carpenter has touched upon. I think, in my paper, which I had the pleasure of reading before you two years ago, I pointed out that abroad we never use bricks, but always used moulded blocks. These are all carefully made and numbered; and if he is furnished with a diagram of the setting it is very easy for even an inexperienced man, only decently clever with his fingers, to put a setting together. In using brickwork, if a brick does not quite fit there is a tendency to jam it up with little wedges, and so on, and sometimes to leave very large joints of mortar. Theoretically, you say it is not done, but retort setters are only human, and after the work is finished these large joints soon burn away or settle, and if there is the slightest settlement it is the first step towards a crumbling up of the whole setting. When I first went abroad I pooh-poohed the idea of blocks, and had an insular prejudice that bricks were the only proper things to use; but I had not been abroad more than three years before I came to the conclusion that my predecessors were quite right in adopting blocks for their settings. If it was right in horizontal settings it must be much more so in inclined settings. With a 20-foot inclined retort on brick piers, if the slightest wobbling takes place it will upset the whole alignment. I have a tracing on the table of what is believed to be a typical setting of a Continental inclined retort, and there is hardly a brick in the setting; it is entirely built with blocks. It would give me great pleasure if some of you, the next time you get a retort, would try this block system, for I feel sure you would be pleased with it. It needs very little mortar, and if the stones are put together with sufficient room for expansion when the setting becomes heated, they last very well. Of course, when a block setting is broken down, there is a lot of waste stuff which is no use; whereas, in a brick setting you can chip up

a brick, and make it useful again somewhere. Still there is a danger in a retort setting, that if any bricks are not absolutely square, they are not fit to be put in, and, therefore, it is better to break them up and get rid of them. There is another matter I should like to ask Mr. Lewis, how the temperatures were ascertained, and the measurements which must be assumed to be correct; and how the differences of mean temperature and the areas were ascertained? In a paper like this, which binds us down to certain facts, you cannot accept the facts unless you know how they were ascertained. It would be of immense value to me to know how the table referring to diagram 10 was obtained—namely, the amount of primary air per lb. of coke consumed without steam and with steam, and how Mr. Lewis got the primary amount of air consumed and the relative work put on the recuperator. This is so important a statement that I am sure Mr. Lewis will do us the pleasure of elucidating what is a little obscure in his otherwise excellent paper. I have much pleasure in thanking Mr. Lewis for the trouble he has taken in this matter, and now call upon him to reply.

Mr. G. P. Lewis: In reference to Mr. Carpenter's remarks with regard to the different settings illustrated. I do not wish to pretend that I should advocate certain of the settings shown at all. The diagrams on the wall are intended to illustrate principles only, as with certain forms of settings you get a certain influence on recuperation. Though the No. 1 setting would answer all requirements from a theoretical point of view, I think it would be obvious that such a system would not be successful in practice. It is simply given as an example for the purpose of providing a unit figure in the tables of comparative efficiency, and has been taken from a German source. Another diagram, No. 12, shows a French setting, which is very similar, but differs in having the regenerators on the opposite side, and would be liable to the same disadvantages. Personally, I consider Figs. 2 and 3 represent the best types of settings, and these are in most general use in this country, and give the best practical results. Taking construction into account they are much superior to the type illustrated by Fig. 1. With reference to the diagram showing two producers heating a setting, that is merely an illustration to show the large amount of surface exposed on the side of the re-

cuperator. It is not intended to represent a good setting at all, but merely to enunciate the principle involved. I think most settings now-a-days have the producer on the one side only. I quite agree with Mr. Carpenter in his remarks as to setting No. 10 as regards local heating between the two bottom retorts, and that applies more particularly when steam is used. In that particular case the temperature is certainly very high at that point between the two retorts. In answering Mr. Helps' question as to how these results were obtained, and also Mr. Marshall's remarks later on, the figures I have given have not been obtained from one particular furnace, but I have taken a large number of results and made an average of them, selecting those examples in which there was the least disturbing influence. The sources in most cases are from continental experience, and I have been as careful as I possibly could to select only those examples which I had reason to believe would be fairly accurate. I have based the tables given, on some fourteen or fifteen series of experiments. The question of taking the temperatures is a very important point, and is one which might be further looked into. It is a very difficult thing indeed to get these temperatures absolutely—for instance, the temperature of the air entering the setting at the point of combustion. It is practically impossible to get that in most instances, and in some cases I believe it has been done by a method in which a circular piece of iron of a specified diameter and length is taken and put in the flue, and allowed to remain until at same temperature, and then removed and immersed in a vessel of cold water, so arranged that by taking the difference of temperature in the water after the metal is fully cooled down the heat can be calculated. The results obtained in this way are superior almost to any others. I have tried a pyrometer of English make, but was never able to get very good results from it.

The PRESIDENT: That is a German drawing. Will you kindly show us a diagram of some settings you have had at work yourself. The reason I ask is this: Many of these settings on the wall are shown with very small nostrils for the exit of the gases. That, I think, is wrong to confine the crude gases in the way they are shown in these diagrams. Either these are very old drawings or else there must be something wrong about them. We know we should not get the best

results with many of these settings, where they are wire-drawing the products of combustion through such narrow channels.

Mr. FOULIS: Perhaps these drawings are not intended as practical illustrations at all!

Mr. LEWIS: That is it; they are simply diagrammatic. No. 2 is the system in use at the Crystal Palace District Gas-works, and generally speaking, it has a very roomy combustion chamber. With reference to the President's remark that I have been specially pleading for the use of steam, that is not my intention at all. It was simply to give certain results that have happened in practice, and I said at the end, what I may say again, that the advantages on the whole lay with steam. Though the President says he does not believe in steam, he appears to use it, because I gather that he has a special arrangement for passing the waste gases so as to heat up a water box, which practically amounts to the same thing as using steam.

The PRESIDENT: I did not mean extraneous steam. I think you have misunderstood me.

Mr. LEWIS: There is a note at the bottom of page 87 which explains what I mean by steam. In conclusion I must thank you for the way in which you have received my paper.

A NOTE ON DISTRIBUTION.

By C. C. CARPENTER.

At the Meeting of this Institution held last June, a paper upon a subject of great interest, viz. "A High-Pressure System of Distribution," was read by Mr. Fletcher Stevenson.

In the course of the discussion which followed, the Author of the present communication was able to furnish some particulars of a high-pressure plant worked during the preceding winter at one of the South Metropolitan Company's Stations.

It is hoped that the interest then evinced in the subject, and the importance of it to gas suppliers generally, may justify the time appropriated to its further consideration.

The productiveness or money-earning capability of the distributing mains stands upon a different basis to that of nearly all the other plant of a gas undertaking. During the winter period of greatest consumption, the whole of the manufacturing plant may be in regular daily and continuous use, and the holders likewise may be drawn upon for the entire range of their capacity. On the other hand, the distributing mains are only fully at work for from about one-fifth of the day in midwinter to one-twelfth in midsummer. Therefore capital expenditure incurred to meet the extra requirements of the hours of heavy consumption is only remunerative in the proportion they bear to the whole year.

The ideal of all suppliers of energy from central stations, viz. a level load line, is not brought nearer of attainment in the case of gas by the rapid extension of its use for heating and power as well as for lighting. In midwinter there will be a serious overlapping of all three demands.

An average daily consumption curve for the South Metropolitan Company is shown in Diagram No. 1.

In order to meet the variations indicated, three courses are open: (1) to make the mains large enough to carry the maximum consumption with a certain minimum pressure; (2) to make them suitable for the normal consumption, and increase

the pressure to supply the maximum demand; or (3) a combination of both.

On Diagram No. 2 are shown the sizes of mains and the initial gas pressure required for the average day shown in Diagram No. 1, and calculated for one mile in length.

This brings out clearly the advantages of high-pressure gas in reducing expenditure on mains.

The scale diagram (No. 3) shows the application of the system of high-pressure supply to the district of the South Metropolitan Company. The larger works are shown at A, A, and from their controlling governors the high-pressure mains run to the distributing centres B, B. The initial governors are so arranged as to give about 3 inches at these centres (governors not being required), and any excess over the proper limit acts as "back-gas" in reducing the quantity sent out by the lower-pressure systems. (In cases where the high-pressure main acts as a feeder along its course, a governor becomes necessary at such points.)

There has now to be considered the extent to which high initial pressure is available. In conjunction with the scheme just described, gasholders have ceased to be entirely depended upon for this purpose. The diagram (No. 4) shows graphically the relationship between holder pressure and capacity in the case of the South Metropolitan Company's forty-five million cubic feet.

It does not need pointing out that when stocks are nearly at their lowest the demand is generally greatest. Moreover, in view of the enhanced lighting value of gas when consumed under some such arrangement as the Somzée Greyson, ideas of pressures at consumers' meters may yet be capable of three- or four-fold expansion in the future.

Some two years ago Mr. George Livesey suggested the use of high-speed centrifugal fans worked by gas engines for the purpose of increasing initial pressures. Under his instructions a fan was installed at Kennington, where the plan has been worked for the past two months with every success. The type used is a special form of the Sturtevant exhauster. One of them, No. 7A, is used to supply gas from one of stations A to B, shown on Diagram No. 3—in this particular case from Kennington to Clapham Junction. It is driven through belting by a single steam engine having a cylinder 5-inch diameter by 5-inch

stroke. The entire cost of the plant, which stands in a space 8 ft. 6 in. square, was 135*l.*, fixed complete. It is estimated to handle upwards of 200 thousand cubic feet per hour.

A larger fan, No. 11A, supplies gas to the governors main inlet from the low-pressure lifts of the holders, and is driven by a 12 horse-power (nominal) gas engine. The cost of this plant, exclusive of connections, was 350*l.*, and it occupies a space measuring 22 feet by 18 feet. The supply main is 3 feet in diameter, and the connections into and out of the fan are 2 feet in diameter. The fan-spindle runs at about 1200 revolutions per minute, and not the slightest trouble or anxiety has arisen since it was first started.

It was possible, by means of the station meters and gas-holder stocks, to measure accurately the duty of the apparatus under varying conditions of pressure, and the results are shown in the following table.

TABLE OF WORK DONE BY No. 11A FAN.

No. of Test.*	Gas Pressure on Main.† Inches of Water.			Gas handled per hour. Thousands cubic feet.	Engine Speed. Revolutions.	Work done by Fan.
	Main Inlet.	Main Outlet.	Difference = Duty of Fan.			
1	6·3	8·4	2·1	1·286‡	184	Supplying gas from holders outlet to governors main inlet. Average speed of fan 1200 revolutions per minute. Average gas consumption of engine 500 cubic feet = at 1*s.* 6*d.* per m. 9*d.* per hour.
2	4·1	7·7	3·6	1·023	182	
3	3·5	8·0	4·5	·932	..	
4	2·9	8·4	5·5	·839	..	
5	2·5	8·0	5·5	·712	..	
6	2·8	8·0	5·2	·699	..	
7	−1·0	6·3	7·3	·631	..	
8	·8	7·7	6·9	·602	..	
9	·4	7·5	7·1	·595	..	
10	− ·5	5·5	6·0	·537	190	
11	·9	7·8	6·9	·472	..	
12	1·4	8·8	7·4	·425	192	
13	3·2	10·6	7·4	·397§	186	

It will be seen from the table that the mechanical efficiency of the fan must be very high—considerably beyond that of any

* Each test is the record over one hour's run.

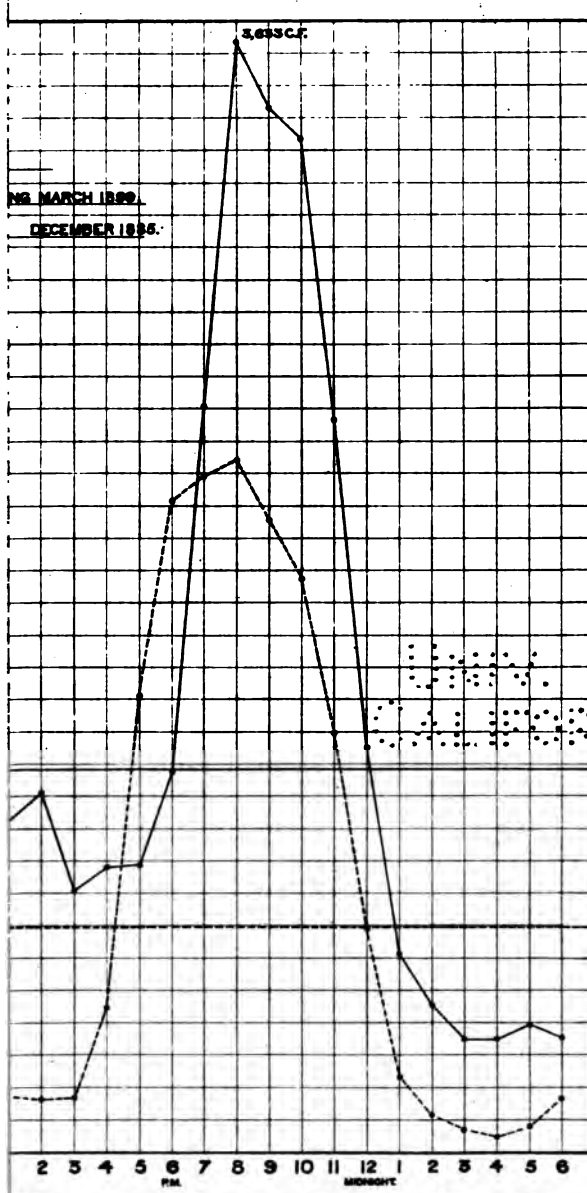
† The pressures given are not those on the connections in and out of the fan, but on the main pipe before and after the by-pass cross valve.

‡ Cost of gas for engine ·007*d.* per thousand.

§ Cost of gas for engine ·024*d.* per thousand.

TROPOLITAN GAS COMPANY—

-Nº1-



AVERAGE HOURLY CONSUMPTION

PHOTO-LITHO SPRAGUE & Cº Lᵀᵈ 4 & 5, EAST HARDING STREET, FETTER LANE, E.C.

—PANY— — Nº 2 —

IAGAL PRESSURE.

	2 TO 4 A.M.	5 TO 7 A.M.	
	9.6	10.0 Sq Ft	
	42	43	INCHES
	2	2	INCHES

AM OF WITHIN ORDINARY LIMITS.

	9.6	10.0 Sq Ft	
	42	43	INCHES
	2	2	INCHES

GRAMRE VARYING.

	42	42	INCHES
	2.0	2.3	INCHES

PHOTO-LITHO SPRAGUE & Co. Ltd 4 & 5. EAST HARDING STREET, FETTER LANE, E.C.

—Nº3.—

—DI DISTRICT.—

RIBUTING STATIONS

BUTING STATIONS

ICATE HIGH PRESSURE

" LOW "

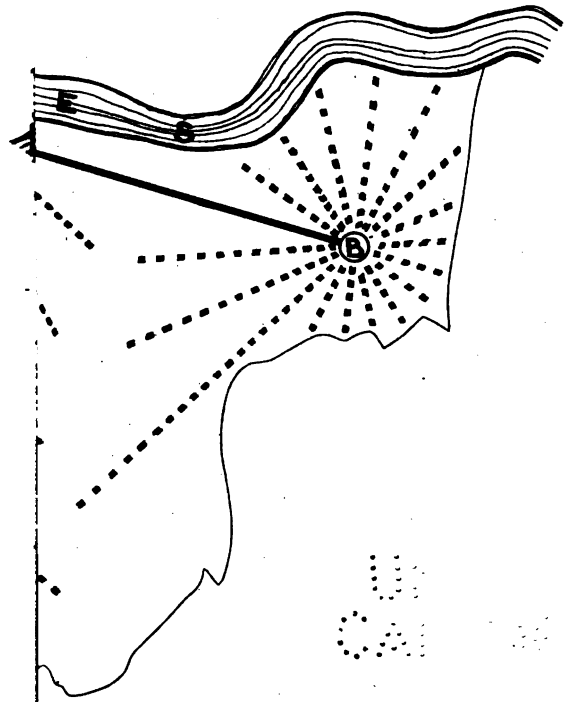
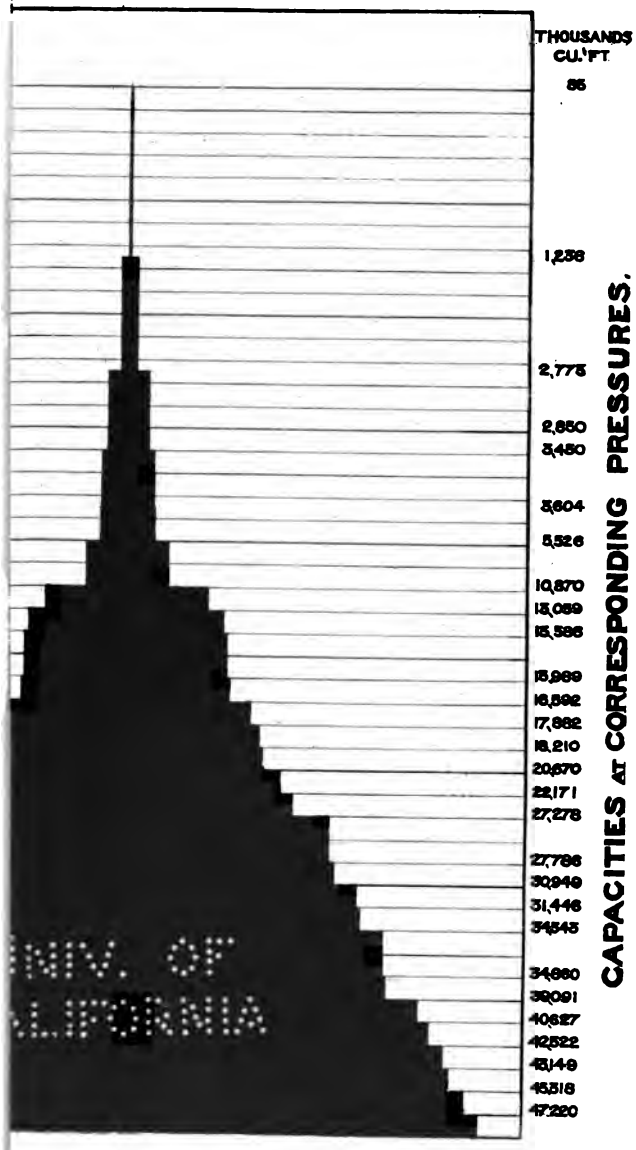


PHOTO-LITHO. SPRAGUE & Cº Lᵗᵈ 4 & 5. EAST HARDING STREET, FETTER LANE, E.C

—Nº4—

POLITAN GAS COMPANY



GASHOLDER CAPACITY

PHOTO-LITHO. SPRAGUE & Co. Ltd. 4 & 5 EAST HARDING STREET, FETTER LANE, E.C.

positive form of exhauster. Its first cost compares equally favourably, and it has, besides, the enormous advantage that, in case of stoppage through any accident to the driving machinery, the full area of gas passage is always maintained.

To gas engineers the problem of economic distribution is of not less importance than economic manufacture, and it is hoped that the brief description given of the plant adopted by the South Metropolitan Company may be of service to those who are considering the means best suited to their wants.

NOTE.—Since the above was written a plant capable of travelling 2½ million cubic feet per hour, driven by direct belting from a Westinghouse three-cylinder gas engine, has been successfully put into operation at the Old Kent Road Works.—C. C. C.

DISCUSSION.

Mr. J. D. ASHWORTH (Portsmouth): I should like to ask the Author if this system is not rather risky where there is only one holder, as is often the case in small works. Of course in a large works where you have three or four holders, and a fan for each holder, it would be all right; but I should like to ask whether in a case like Portsmouth, where I work out of one holder, it would not be a risky thing to do. Another question is whether as the holder lowered, the speed of the fan would not require to be exceeded to make up the pressure given by the holder. I understand the idea is to give sufficient initial pressure in spite of the lightness of the holder. From what I can see the lightness is due to the design of the holder more than anything else, because, I presume, of the inner lifts going outside the columns, and not having the ordinary carriages on or something of that kind.

Mr. FLETCHER: I should like to know if Mr. Carpenter means in a large works, where a large amount of gas is supplied, to have small instead of large trunk mains; what would be the result if the fan suddenly pulled up when the heaviest consumption was on? What would be the effect if the pressure was suddenly lowered in that way?

Mr. W. KING (Liverpool): About twenty-two years ago this

subject came before us in Liverpool, inasmuch as a large connecting main between two of our works was found to be getting too small. We then introduced pumping machinery, which is still employed, and I believe the system is adopted at other places, of forcing the gas from one works to the other by machinery, in consequence of the comparatively low pressure of the holders. That was not done so much with the idea of pumping directly into the distributing mains as to take the gas from one works to the other, where it was put in a gasholder; and this became merely an accumulator. If the demand at the distant works is greater than the amount of gas sent by the exhausters the gasholder begins to descend to supply the deficiency. If, on the other hand, the gas which is sent to the distant works is more than the governors require the gasholder begins to rise, and acts as an accumulator. It is a very interesting question that Mr. Carpenter has brought before us, and if by the adoption of this system, or a modification of it, an enlargement of mains is avoided, it is evident it will be a very great advantage not only in the saving of capital outlay, but will also avoid the nuisance and trouble occasioned to the public by tearing up large and important streets.

Mr. J. W. Helps (Croydon): I am afraid I have very few ideas on this subject, as the necessity has not arisen in Croydon for treating the matter in such a way as that suggested by Mr. Carpenter. I quite appreciate the great difficulty which does exist in all companies where the large holders have inner lifts which give a very light pressure. At Croydon, having several holders, we are able to get the heavy holders full by day, to give enough pressure at night, and work out the lifts which are very light during the day. It does seem to me, however, that one of the difficulties in connection with this matter is the difficulty which would arise in the event of the blower suddenly pulling up. They may be supplying the gas at 7 or 8 inches and the pressure of the holder be only 3 or 4 inches; and though it might be sufficient to keep the lights from going out entirely it would cause a deal of dissatisfaction, and bring in a number of complaints from consumers. Perhaps Mr. Carpenter can give us some further information on that point. I would also like to ask whether it is necessary to have

the fans in duplicate. Apparently, from the small amount of money spent, that is not the case. I should have thought it advisable, as the fans must be working at high speed at times; and high speed naturally means a good deal of wear and tear and some likelihood of a break down. Evidently Mr. Carpenter has great faith in them, but I should like to hear whether he thinks it necessary to duplicate.

Mr. S. MEUNIER (Stockport): With regard to this question of distribution I remember at last year's meeting on Mr. Stevenson's paper a suggestion was made that, instead of forcing the gas through these mains at a high pressure, and so increasing the probable loss by leakage, it might be possible to put a fan or exhauster at the far end of the district and so increase the pressure onward from that point. Since then I have attempted a scheme on a small scale, by exhausting an independent main between two of my works, to see what the result would be. I have certainly found a distinct improvement, inasmuch as I have not the slightest difficulty in getting into the gasholders at our second station at least double the quantity of gas in the same period of time as I did before by simply forcing it. The thought struck me last year as to whether it would not be quite as well or even better—taking into consideration the leakage which is likely to take place by increasing the pressure up to 12 inches—to follow the example set by our friends the electrical engineers in their manner of supplying from sub-stations; it appears to me that it might be advisable, more especially in view of the fact that it might be a rather risky experiment to increase the pressure too much. I should like to ask Mr. Carpenter to give us his views on the question of the establishment of a small sub-station somewhere, where he could draw from the trunk main and distribute the gas through a district, and whether this would not answer the purpose equally well as forcing the gas direct from the station at a high pressure.

Mr. T. A. GUYATT (Ely): I notice in the table against Nos. 7 and 10 there is a minus sign for the main outlet. I take it that represents the vacuum.

Mr. CARPENTER: That is pressure below the atmosphere. There is 1 inch of pressure in the one case, and 6·3 of pressure in the other.

Mr. GUYATT: I should like to ask Mr. Carpenter whether he has any difficulty with the holders in those circumstances. I presume the vacuum would continue into the holders if they happened to stick or hang; and whether he has any difficulty in working them with a vacuum in that way.

The PRESIDENT: I should like to ask Mr. Carpenter whether he does not think it necessary to duplicate these fans. I have some seven or eight of them at work, not for gas-works but for a cement works; and every now and then they go to pieces entirely, there is no question of repairing them. Therefore, where so much depends on them, and the outlay is so small, I should think it well to duplicate them. I believe I was guilty, last year, of asking the question which Mr. Meunier has asked to day as to exhausting through the mains, and as I did not get a convincing reply, I shall be glad if Mr. Carpenter will deal with it more thoroughly.

Mr. C. CARPENTER: I am not sure whether I have made my case as clear and emphatic as I desire. The reason, probably, is that the diagram does not appeal to everyone. The main point about it is that it is a scale diagram on the utility of gas mains taken on an average day, midway between midsummer and midwinter. I think it brings out the points which the electricians are suffering from greatly as well as ourselves, the high peak, which means that only during a portion of the 24 hours is the outlay on the mains productive. The problem, I take it, is how we can make them more productive, and following up that view of the case, I think we shall succeed more completely if we look to the initial pressures more than we have done hitherto. In order to bring this out more clearly I have prepared the second diagram, which shows the pressures required, keeping the mains equal. This is to a great extent the essence of the paper, whether it is not better, to meet any difficulty as to the supply by making the existing mains more productive, instead of increasing the expenditure on mains by laying new ones. Why should we spend so much money on mains we make so little use of, as to distribute the gas with an initial pressure of only 3 inches? There is absolutely nothing in the suggestion of increased leakage through employing high pressure. A considerable amount of gas is distributed in the Metropolis at high pressure. Take the case of the north of London, where the bulk of the gas is sent from

Beckton at an initial pressure of somewhere about 24 inches; but the leakage is not excessive, because, according to Field's analysis, they stand very well as regards unaccounted-for gas. For many years I have had experience of high-pressure mains of large size (up to 30 inches), working with them at a pressure of from 12 to 15 inches. And the only escape I have had on them was due to the making of a big sewer in a very busy part of the district. Apart from that I have never had a leak on those high-pressure mains of about one-third of a mile long. With regard to the duplication of the fans I have not considered it was necessary, and for this reason—the fans are not running continuously, they are running only during the hours of maximum load. There are conditions under which, when the holders are quite full, it is not necessary to run them at all; and generally speaking, they are only working for a few hours. Up to now I have not had any trouble with them in the least degree; I have never had a hot bearing or any difficulty at all. Supposing the fans were working all through the 24 hours I should consider a duplication necessary. For instance, in the case of one works where the gas is made at one station and sent down to be measured and stored half a mile away, in midwinter there is a great deal of trouble owing to back pressure thrown by the mains, meters and holders. I am arranging to get over that next winter by putting down fans to deal with the whole make. The fans will draw the gas from the inlets of the meters and force it through them into the holders. The fans there will be working throughout the 24 hours, and in that case I think it essential to have duplicates. But with fans working for a short time in the day (as these fans are), I do not think it is necessary. It is not as though (as in the case with an exhauster) when the apparatus stops you stop altogether. In the case of an accident—and in my experience that is very unlikely—you are simply suffering from a reduction in the pressure. With respect to the speed at which the fans are running there is nothing remarkable about it. The speed is, in the case of the large fan, 1200 revolutions a minute; and if the straps are wide enough to transmit the horse-power of the engine without having them too tight there is no difficulty in running them continuously. I had information some two or three weeks ago of a plant in America which has been working under similar conditions to this, and the fans have been running

continuously for many weeks on end. I have written to America for information; but it has not yet come to hand, therefore I can only say that the plant is used for a similar purpose to that I have described by the Consolidated Gas Company of New York. With respect to the question of the large holders of the South Metropolitan Company, the scheme of high pressure distribution does not depend upon the weight of the holders. I suggest that the fans can be profitably utilised in two ways, first of all by increasing the initial pressure at certain portions of the district, in other words there should be a high-pressure system and a low-pressure system, and for the high pressure the small fan should be used. The second point is that when the holders are low (uncupped) and the inner lifts only available, we have a ready means of providing whatever initial pressure is required. I have heard of cases of works which stopped on Sundays, where it has not infrequently been necessary to work a portion of the day at any rate, not because of any shortness in the gas stock, but because it was locked up in holders which are not heavy enough to give the required pressure. There is the question of sub-stations which Mr. Meunier has raised, but I would point out that the method described requires no extra cost in rent or labour. The plant is put down at the gasholder station; and when the man starts the engine he sets the fan running; and it runs as long as it is required without any extra duty or attention. Not only that, but it is put down on land which is already available, whereas, if we fixed it in a cottage in an outlying part of the district there would be the rent of the cottage and the man's attendance there, going on over the whole of the year. I am not going to say there are not cases where it is advisable to do as Mr. Meunier says, but I certainly think the most economical plan is to do it from the distributing station and use it in the direction required.

Mr. MEUNIER: I take it in your case you had already your high-pressure mains laid?

Mr. CARPENTER: The mains were not originally laid as high-pressure mains; but we cut off the intermediate connections and converted what was an ordinary low-pressure main into a high-pressure one.

Mr. MEUNIER: Suppose it is a question with you whether

you shall establish a sub-station or lay a special feeding main, which would you prefer to do?

Mr. CARPENTER: If it was impracticable to do what we did, cut off the connections near the works and supply them from the through governors, then I should have no hesitation in saying that your (Mr. Meunier's) case is properly solved as you solved it.

INCANDESCENT MANTLES.

By VIVIAN B. LEWES, F.I.C., F.C.S.

There is nothing more wearying to the practical man than to listen to the preachings of the scientist who imagines that the thoughts born within the four walls of his study are superior to the hard-earned experience of years of labour; and nothing is farther from my intention than to impose this suffering upon you. There are, however, sides to many questions which can be made clear: details, the explanation of which can help; and innovations, the description of which will interest those employed in actual every-day work. It is in this way that lectures can be made most valuable, while the more practical working experiences find their most fitting record in the discussion which every lecturer hopes to excite.

It was long before the incandescent mantle came to the assistance of the gas engineer in his fight against the threatened encroachment of the electric light, that the name of Dr. Auer von Welsbach became known to the scientific world as one of the most promising students in the domain of the rare earths that the world-famous laboratories of Heidelberg and Vienna had produced. Boiling a solution of some of these rare oxides, and using a ragged sheet of asbestos card to shield the beaker containing the solution of the salts from the fierce flame of the Bunsen burner, he noticed that a small quantity of liquid which had boiled over and evaporated on the projecting fibres at the edge of the card, endowed them with the power of becoming brilliantly incandescent under the exciting heat of a non-luminous flame. Seizing the clue so obtained, Welsbach set himself to solve the problem of how to utilise the manifestly high light-emissivity of these bodies as a practical aid to artificial illumination; and the result of his quest has been to place the gas industry well beyond the reach of electrical competition for many years to come, and to ensure fame and more substantial reward to the keen worker whose appreciation

of the importance of his discovery, and determination during an up-hill fight of some ten years, have practically resulted in one of the most phenomenal successes of modern times.

The term "rare earths" is one of those anomalies which mar the vaunted precision of science; as, though it might justly be applied to the oxides of many metals, it was in 1885 used to designate a small band of metallic oxides which occur in certain rare minerals of which cerite and gadolinite may be taken as types. The term "earth" was applied to such bodies as the oxide of chromium (Cr_2O_3) and alumina (Al_2O_3); while the "alkaline earths" were the calcium and magnesium groups. These rare earths were generally considered to be—

Cerium oxide (Ce_2O_3).
Lanthanum oxide (La_2O_3).
Didymium oxide (Dy_2O_3).
Yttrium oxide (Y_2O_3).
Erbium oxide (ErO_{22}).

together with some others even scarcer; and these are divided into two groups—

Cerite Earths.	Ytterite Earths.
Cerium oxide.	Yttrium oxide.
Lanthanum oxide.	Erbium oxide.
Didymium oxide.	

which are easily divided from each other by the action of an excess of potassic sulphate; the cerite earths forming "alums," which are insoluble in potassic sulphate, and so separate out, while the ytterite earths remain in solution. These rare earths are all bases. There are, however, other metallic oxides equally rare which play an important part in mantle making, but cannot be classified with them. Thoria (THO_2) and zirconia (ZrO_2) are not earths, and in some combinations show rather an acidulous than a basic tendency. These two metals, thorium and zirconium, are classed with titanium, silicon, &c.

It was with the study of these oxides that Welsbach was most concerned at the period when his early attempts began to assume tangible shape; and having discovered the possibility of making a mantle to fit the shape of a non-luminous Bunsen flame by soaking a cotton fabric in a solution of salts of the rare earths, and then burning out the organic matter in such a way as to leave a ghost of the departed threads built up of the oxides of the metals used—thin enough to be excited to

luminosity by the heat of the flame, and yet resistant enough to retain its shape under the temperature to which it was submitted—he took out his celebrated patent of 1885, which has proved an efficient first line of defence against those who, left outside the charmed circle, have yet hungered for the baked meats within.

In the 1885 patent, Welsbach protects the idea of making a mantle by saturating the cotton fabric and then burning off, using mixtures of the salts which he gives as—

60 per cent. of zirconia or oxide of zirconium.
20 „ „ oxide of lanthanum.
20 „ „ oxide of yttrium.

The oxide of yttrium may be dispensed with; the composition being then—

50 per cent. of zirconium.
50 „ „ oxide of lanthanum.

Instead of using the oxide of yttrium, ytterite earth, and instead of the oxide of lanthanum, cerite earth containing no didymium and but little cerium, may be employed.

As a commercial article, the mantles made under this patent were dire failures. They had an illuminating power which varied from three to six candles per cubic foot of gas consumed, and were so friable that the mantles of to-day seem giants of strength as compared with their puling forefathers. They, however, fulfilled the important function of launching the idea of the mantle. Hardly had the patents been taken than Welsbach made the further discovery that, by going outside the group of rare earths, and by replacing zirconia by thoria as a basis, increased life and strength could be given to the mantle; and this was protected by the patent taken out by him in 1886. In this patent he protects the use of thoria alone or in admixture with zirconia, lanthana, yttria, didymia, erbia, magnesia, or alumina.

During the next few years, the composition of the mantles made by the Welsbach Companies was of a very variable character; but the largest proportion of them consisted of commercial thoria, and gave a light of six to eight candles per cubic foot of gas—this being due to the fact that the material used was not pure, and contained traces of ceria, which gave it the

power of emitting what was then a considerable amount of light. Pure thoria gives a practically non-luminous mantle; and with chemically pure material the light obtainable is under 1 candle per cubic foot of gas; while even now a mantle made from the commercially pure thoria, manufactured for mantle making, gives a light of from four to five candles per cubic foot. This is entirely due to the difficulty of separating the last traces of ceria; and as 0·1 per cent. of ceria causes thoria to give about five candles per cubic foot of gas, it is difficult to obtain a sample which does not give a certain amount of light.

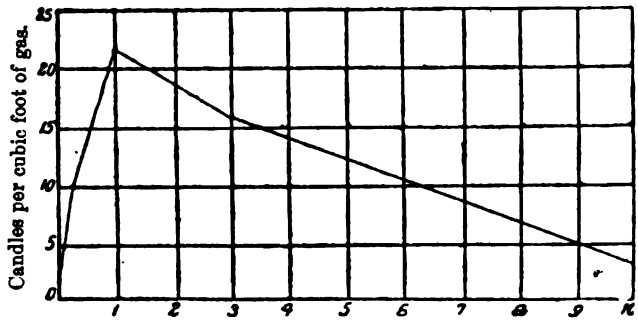
The use of ceria together with thoria is mentioned in some of Welsbach's early foreign patents; but the exact date at which it was first realised that traces of ceria had the marvellous effect on the light-emissivity of the thoria mantle that we find in the mantles of to-day, is not very clear. It is evident, however, that the advantage of the presence of small quantities of ceria was beginning to be realised by 1891, when Mr. W. Mackean, the Chemist of the English Welsbach Company, read a very interesting paper before the Society of Chemical Industry,* and pointed out that ceria is by no means a disadvantage in small quantities, as it adds to the constancy of the illuminating power. He gave a table showing the influence of the presence of ceria in the lighting fluid, and also the influence upon the light which increasing percentages of ceria have. Thus, for instance, the ordinary lighting fluid contains 0·25 per cent. of ceria, and gives 25 candles for a consumption of 2½ cubic feet of gas, or 10 candles per foot; while increasing the percentage of ceria in the fluid to 0·5 reduces this to 18 candles for 2½ cubic feet. When 1 per cent. of ceria is added, a further reduction to 13½ candles for the 2½ cubic feet is found; but while the candle power lost 43·2 per cent. in 1000 hours with the 0·25 per cent. of ceria, it only lost 12·6 per cent. in one experiment, and 28 per cent. in another, with 1 per cent. of ceria present in the original fluid. He also, in the same paper, gave the following as a composition for a mantle giving a yellowish light: lanthana, 40 per cent.; thoria, 28 per cent.; zirconia, 30 per cent.; and ceria, 2 per cent.—showing that at this period the use of small quantities of ceria in mantles containing thoria was by no means unknown.

Later on, in 1893, Mr. Moeller, having clearly realised that

* See 'Journal,' vol. lvii. p. 345.

commercial thoria contained traces of ceria, and that it was owing to this that the earlier mantles gave any light, took out a patent in which he sought protection for thoria in combination with very small traces—not exceeding 1 or 2 per cent.—of certain other rare metals, such as uranium, cerium, terbium, neodymium, samarium, praxeodymium, yttrium, and lanthanum. The mantles of to-day nearly all consist of 99 per cent. of thoria and 1 per cent. of ceria, as, although several of the oxides mentioned, in minute traces, endow a non-luminous thoria mantle with the power of emitting light, yet ceria so far transcends the others in its capacity of not only exciting luminosity but of keeping up the illuminating power over a long period, that, as far as our present knowledge goes, it is needless to look beyond it.

An absolutely pure thoria mantle gives less than one candle per cubic foot of gas consumed; a pure ceria mantle gives but little light, and of a red nature. So that, for all practical purposes, the ingredients when used alone are valueless. But the smallest addition of ceria to the thoria causes a rapid leap up in its power of light-emissivity, which reaches its maximum when from 0·9 to 1 per cent. of the total oxide consists of ceria. Further additions cause a rapid falling off in the light; while the light emitted first assumes a yellowish and then a reddish tint as the percentage increases. The following curve



PERCENTAGE OF CERIA WITH THORIA.
Curve showing the effect of percentage of ceria on the light emitted by a thoria-ceria mantle.

of candle power and percentage of ceria shows the average result obtained; but it must be borne in mind that certain

traces of impurities, derived from the ash of the cotton and from the salts used, lower, to a certain degree, the absolute candle power, although they do not affect the general contour of the curve.

Several attempts have been made to explain the wonderful power of light-emissivity possessed by the thoria-ceria mantle. Dr. Drossbach was of opinion that the rare earths had a special action in converting heat rays into light rays, and that the molecules of ceria acted by bringing the heat vibrations of thoria to the most favourable state of resonance with the vibrations of the hot-flame gases. Dr. Moscheles and Dr. Killing both pointed out that cerium formed two oxides, and that other metals having the same characteristics would act as exciters when used in the proper proportions. Both attributed the high incandescence of the mantle to changes in the state of oxidation increasing the intensity of combustion on the mantle surface; while Dr. Killing pointed out that a catalytic action also probably took place. Dr. Bunte has given by far the best exposition of the theory of the incandescent mantle, which if it does not make all points clear, yet offers a simple and probable explanation of the observed phenomena, which he ascribes to intense local temperature due to the ceria exercising a power of attracting oxygen and causing its combination with the flame gases.

The remarkable influence which ceria exerts in awakening light-emissivity in the mantle becomes still more remarkable when one considers that, although the percentage by weight of the ceria is only one, yet that by volume it is enormously less. When nitrate of cerium is converted into ceria by the action of heat, little change of volume takes place; but when nitrite of thorium is decomposed in the same way, its conversion into oxide is accompanied by an increase in bulk of an extraordinary character—the substance swelling up, and producing a light powder occupying many times the bulk of the original salt—so that in the finished mantle small indeed must be the space occupied by the exciting ceria.

This seems to point to some specific action on the part of the ceria; and cases are not unknown in which dilution with some inert material increases physico-chemical action of the kind one would expect of the ceria. If port or claret be shaken up with powdered charcoal, which consists of nearly pure

carbon, and the mixture is then filtered, the colour is but little changed; while if animal charcoal, or some of the artificially prepared imitations of it containing only 10 per cent. or less of carbon distributed over the surface of inert mineral matter be used for the same purpose, the liquid is absolutely decolorised.

Another example which bears closely upon the case of the ceria is to be found in the action of platinum upon mixtures of hydrogen or coal gas and air. If a piece of platinum foil be heated to redness in a Bunsen flame, and the gas be then turned out, and afterwards turned on before the platinum has had time to grow too cool, it again becomes heated to redness in the stream of gas and air, and continues in this condition as long as the gases are passing over its surface; while if brought to what would have been the outer envelope of the flame, had the gaseous mixture been alight, the temperature is so increased that the ignition-point of the gas is reached.

The action here is what is known as a catalytic or surface action, and it is due to the fact that platinum has the power of condensing gases upon its surface, and in doing so renders them so chemically active that combination between the condensed gases is often induced. In the cases of the coal gas and air, enough heat is evolved on the surface of the platinum to raise it to redness. The result being due to surface action, it is manifest that an increase of the surface must increase the activity of the substance, and if, instead of taking metallic foil with its comparatively small area of exposed surface, spongy platinum made by reduction from a platinum salt or asbestos coated with the reduced metal be employed, ignition of the gaseous mixture without the preliminary heating takes place.

The fact that the platinum foil remains red-hot in the stream of coal gas and air which is only at atmospheric temperature, at once shows that the heat evolved by such an action is localised in the body starting the action, and it is manifestly possible—and indeed probable—that the very minute particles of ceria scattered over the surface of the inert thoria, and so subdivided as to be capable of easy and rapid heating to a very high temperature, may give rise to an action of the same kind. Indeed, one knows that to a certain extent this is so, because if the mantle-burner be turned off and again turned on while the mantle still remains hot, the mixture of gas and air is re-ignited,

though the rod and mantle material are manifestly below the ignition point of the gas; and the fact that this does not take place with a pure thoria mantle is a fairly good proof that it is the ceria, and not the thoria, which is acting.

Dr. Bunte has found that thoria had no influence in bringing about the combination of hydrogen and oxygen, and the temperature at which the two combined to form water was the same whether thoria was present or not; but that the presence of ceria caused them to combine at 660° Fahr., instead of at 1200° Fahr. This being so, the question arises as to what the action can be that the ceria induces—the localisation of the heat from which causes its minute and subdivided particles to glow with so high an incandescence.

When in a Bunsen burner the admixture of gas and air has been carried to the extreme limit, so that what would have been the inner cone of the Bunsen flame settles down as a green and seething sheet on the gauze of the burner top—being, indeed, only prevented from flashing back in the tube by the conducting power of the gauze and the accelerated rush of the gas and air mixture through its meshes—the combustion is being completed in two stages; the first taking place on the surface of the gauze, where the hydrocarbons of the coal gas undergo incomplete combustion at the expense of the oxygen of the admixed air, yielding carbon monoxide and hydrogen, together with small quantities of carbon dioxide and water vapour. It is the combustion of the carbon monoxide and hydrogen which gives the outer flame in which the mantle is heated; this combustion entirely taking place at the expense of the oxygen derived from the air surrounding the flame, and not from the air originally mixed with the gas in the burner-tube. It is a mistake to speak of this outer flame as a "solid flame"—an expression often used in connection with burners in which sufficient air is introduced with the gas to flatten the inner zone on to the gauze—as it is merely the structureless flame which is always obtained on burning gases like carbon monoxide and hydrogen, which burn only in one stage. Any user of mantles knows perfectly well that it is only in the edge of this outer flame that the mantle material acquires its true incandescence; this being due to the fact that it is only when the maximum quantity of air and the carbon monoxide and hydrogen meet that the highest temperature is attained, and it is here

that combustion is at its fiercest, and that the catalytic action of the ceria creates points of high intensity.

The view put forward by Moscheles and Killing may be shortly stated as follows. Cerium is a metal which exists in two states of oxidation—a lower or cerous oxide Ce_2O_3, and the higher or ceric oxide CeO_2—and it is easily conceivable that in its highly subdivided condition, and at a high temperature, exposed as it is to the high-reducing action of hydrogen and carbon monoxide, which tend to take oxygen from it and convert it into cerous oxide, and also to the oxidising action of the air, which tends to again build it up into ceric oxide, a continual oxidation and reduction is taking place; the abstraction of oxygen from the air, and its liberation to combine with the reducing gases on the surface of the ceria, raising these attenuated particles far above the temperature of the flame. It is quite clear that, whether one accepts the Killing theory of dual oxidation or Bunte's of catalytic action of the ceria, one arrives at an explanation of the fact that, unless the mantle be just in the right position so that both the air and the flame gases have access to it, the luminosity of it is practically destroyed.

It may be roughly stated that there now exist two classes of theory with regard to the mantle. The first is that the ceria or ceria and thoria exercise some occult power of converting heat rays into light. The second, the theories of Killing and Bunte, which ascribe the wonderful light-emissivity to the exalted temperature brought about by local combination due to the power of the ceria in attracting oxygen; and it matters little whether this be brought about by a purely chemical or by a physico-chemical action.

It is clear that if the light be due to the conversion of heat rays into light, on heating the material out of contact with air, the same differences in their power of emitting light should be observed as exist in the mantle; and several experiments have been made in order to find if this were so or not. Dr. Bunte took a thick-walled tube of arc carbon, having the walls of its middle portion reduced for a length of four inches to a thickness of 0·059 inch, and heated it by an electric current until the middle portion attained a most intense white heat, far above 3630° Fahr. In order to prevent combustion and loss of heat, the middle of the tube was embedded in magnesia, over which

asbestos paper was wrapped. Small square prisms—0·59 inch long by 0·28 inch wide—of magnesia were coated with the substances to be examined; and each was cemented to a similarly shaped piece of carbon or magnesia, so that the two adjoining faces consisted of the two substances to be compared. On placing these double prisms in the tube, it was possible, with certain precautions, to observe the relative intensities of the radiation by comparing the two halves of the surface visible in the tube. These researches showed very small differences in the intensity of the radiation from carbon, magnesia, pure oxides of thorium and cerium, and the Welsbach mixture.

Within the last week confirmation has been give of Dr. Bunte's results by an extremely interesting paper communicated to the Royal Society by Mr. A. A. C. Swinton, in which he enclosed the luminous materials in a vacuum tube, and subjected them to bombardment by means of cathode rays, which would raise them to a very high temperature, as it is possible by such a method to melt platinum and glass, and to bring finely divided carbon to bright incandescence. The mantle to be experimented on was mounted in a platinum wire frame, and placed between the two electrodes, so that as the electric current alternated, and each electrode became in turn the cathode, the mantle was subjected on alternate sides to cathode ray bombardment. Experiments were made with mantles consisting entirely of ceria and thoria, both separate and mixed in different proportion; and in order to obtain accurate comparisons between the pure oxides and different mixtures, the mantles were made in patchwork—each mantle being made up of two to four sections separately impregnated with different solutions, and then sewn together with impregnated cotton before being burnt.

With a compound mantle prepared in this special way, composed one-half of pure thoria and the other half of a mixture of 99 per cent. thoria with 1 per cent. ceria, it was found that after exhaustion, on starting the cathode discharge, the thoria *plus* ceria heated up to incandescence more rapidly than the pure thoria, and on stopping the discharge cooled more rapidly. Further, when at full incandescence, and observed through a dark glass, the thoria *plus* ceria was slightly more luminous than the pure thoria, though the difference was very small—probably not more than 5 per cent. Owing to the

difficulty of obtaining a constant vacuum, accurate photometric measurements were not possible; but the amount of light under favourable conditions was roughly estimated at at least 150-candle power per square inch of incandescent surface—this being obtained with an expenditure of electrical energy in the secondary circuit, at about 8000 volts pressure, of approximately 1 watt per candle. The amount of exhaustion suited to give the best results varied with the dimensions of the tube and the conditions mentioned in the paper, but was approximately about 0·00005 atmosphere; the maximum luminosity being obtained when the dark spaces of the two cathodes just crossed at the centre of the bulb. Owing to the large amount of gas occluded by the mantle, a proper degree of permanent exhaustion was very difficult to arrive at, and required continuous pumping for many hours with the cathode rays turned on at intervals. Even then, the conditions of maximum luminosity were exceedingly unstable, owing, on the one hand, to the further liberation of occluded gas, and, on the other, to the rapid increase in the degree of exhaustion on account of absorption of the residual gas by the electrodes. That such absorption probably took place in the aluminium electrodes, and not in the mantle, was demonstrated by other experiments with a tube in which there was no mantle, but only two electrodes of aluminium wire.

These experiments all point to the fact that the idea of a mixture of 99 per cent. of thoria and 1 per cent. of ceria having the peculiar power of converting heat rays into light, while thoria and ceria alone have not this power, or at any rate only have it to a very limited extent, is not tenable; otherwise the same difference would have been noticed when the materials were heated either in the carbon-tube furnace or in the vacuum tube. This undoubtedly gives great support to the second theory.

It has been pointed out that the amount of ceria in the mantle is so extremely small that it seems hardly credible that any surface action that it possessed would play an important part in the production of luminosity; but Dr. Bunte answers this objection by saying that, according to Davy's theory, the illuminating power of an ordinary gas-flame is due to the particles of carbon which are separated from the gas and raised to a white heat. The carbon arises chiefly from the

decomposition of the heavy hydrocarbons ethylene and benzene, which form together about 5 per cent. of the volume of the gas. Assuming, for the sake of simplifying the calculation, that all the carbon of the benzene and half that of the ethylene is separated and heated to incandescence in the flame, it may be calculated that about 54 milligrammes of carbon are separated from a litre of good coal gas—23·6 grains from 1 cubic foot. Thus 4 per cent. of ethylene and 1 per cent. of benzene give, per litre of gas, 60 c.c. of carbon vapour from the benzene and 40 c.c. from the ethylene—in all 100 c.c., which is equal to about 54 mg. of carbon. The volume of the luminous portion of a flame having a consumption of 5·297 cubic feet per hour, and an illuminating power of 17·5 candles, is about 2 c.c. at 32° Fahr. There is therefore in it $(2 \times 54) \div 1000$ mg., or 0·1 mg. (0·0015 grain) of incandescent carbon. Such an extremely small quantity of incandescent carbon as 0·0015 grain, gives the luminous surface to the gas-flame, and emits a light of 17·5-candle power. Now the 1 per cent. of ceria in the Welsbach mantle amounts to about 4 mg. (0·06 grain) per mantle, or about forty times the quantity of incandescent carbon in an ordinary flat flame. The quantity is therefore quite sufficient to explain why the Welsbach burner may give a light of 60 candles, while the flat-flame or Argand burner furnishes only 17·5 candles.

The only other legalised mantle at present before the public is the Sunlight, the ingredients of which consist of alumina and the oxides of chromium; and it is interesting to see how far the light yielded by this mantle can be attributed to the same action as in the case of the Welsbach. If a mixture of alumina or alumina and zirconia, with a very small percentage of chromium, be employed, a very high candle power is produced, which, however, soon dies away, owing to the volatilisation of the chromium compound; while if the amount of chromium present be increased, the mantle acquires a more ruddy light, and retains its illuminating power for a much longer period. So that with a proper percentage of chromium a candle power of 10 to 11 candles per cubic foot of gas can be obtained for a period of 400 to 500 hours; and it is noticed that the chromium, which on first burning shows as green chromium oxide, rapidly combines with the alumina to form a pink compound, which has much the same composition as the ruby. It is quite pro-

bable that the increased life given by the larger quantity of chromium is due to the fact that the lighting power of the mantle is really dependent on small traces of the oxide of chromium, and that as this gradually volatises off from the surface of the mantle, some of the pink compound gets dissociated by heat, and supplies a fresh portion of chromium oxide to the surface of the mantle—this pink compound being far less volatile than the chromium oxide itself.

Thoria, as far as the life of the mantle goes, is perhaps the most important constituent, as there is no other known oxide which will stand heat for so long a period without being affected by it; and the getting away from shrinkage in the mantle was one of the chief steps which led from the failure of the early mantles to the success achieved by the later ones. Moreover, thoria is a body having a very low specific heat, and owing to its bulk, when produced from the nitrate of thorium by the action of heat, it is a good non-conductor, so that the temperature created on the surface of the ceria particles is more readily localised.

Within the last few years attempts have been made to attack the question of mantle making from a different standpoint. Admitting the superiority of thoria with its 1 per cent. of ceria over other mantle mixtures, efforts have been made to obtain mantles of filaments of this mixture upon the principle under which the old Clamond basket was made. Clamond produced his incandescents by making a paste of magnesia with acetate of magnesia in solution, and moulding the mixture into threads by squeezing through holes in a plate. The threads, while plastic, were wound to the required shape on a mandrel or mould, the still moist threads being pressed together and made to cohere at the points where they crossed each other, and then, on baking, the acetate luting burnt to oxide. The reduction in size of the mass to be rendered incandescent was a great advance, and enabled incandescence to be produced by a burner instead of a blow-pipe; while Welsbach's discovery—or rather adaptation—of the principle of saturating a fabric and incinerating, created a new era in incandescence.

As was natural, attempts were then made to reduce still further the size of the filaments in the Clamond basket, and on November 4, 1890, Lungren patented a distinct advance. It was found that if one made a plastic filament as Claymond had

done, but finer in substance, it dried very quickly, and on attempting to make the material cohere at the crossing of the threads, those first wound on the mandrel (being drier than those wound across them) were harder, and on pressure being applied, cut through the softer threads instead of welding with them. Finding this, Lungren patented the idea of making a plastic mass of some elastic material charged with refractory earths or metallic oxides, expressing from such mass fine wires or threads, weaving or interlacing the threads into a fabric from which the cone or mantle could be made, and then burning out the combustible elastic binder. In making this binder he gives mixtures of glue with glycerine, india-rubber dissolved in naphtha or boiled linseed oil, as examples; but he also says that a variety of materials may be used.

One of the most remarkable developments of the last fifty years has been the wonderful way in which the lower form of gun-cotton, known as collodion cotton, has been utilised for commercial purposes, and at the present time it bids fair to invade the territory of incandescent mantle making. It was in 1838 that the chemist Pelouze drew attention to the fact that when paper was acted upon by the strongest nitric acid, it increased in weight, and acquired the property of burning with enormous rapidity; while as early as 1813 Braconnot had prepared a substance called "xyloidin" by acting upon starch, linen, and sawdust in the same way. It was not, however, until 1845 that any serious attention was directed to the use of such substances as explosives, when Schonbein first called attention to nitrated cotton wool, and advocated its use as a substitute for gunpowder—showing that in explosive energy it was far superior to it.

Experiments were at once instituted on a large scale; and its manufacture was carried on in England, and also on the Continent. But in 1847 a very serious explosion occurred at the works at Faversham in which it was manufactured by Messrs. Hall; while a year later an even more serious explosion followed in the gun-cotton factory at Bouchet, near Paris. As no reason could be assigned for these and similar explosions, gun-cotton was looked upon as too dangerous an explosive for ordinary use; and its manufacture was for a time discontinued.

During this brief period, however, it had been discovered that if the strength of the nitric acid employed in the manu-

facture be slightly reduced, a compound was formed which had the property of dissolving in a mixture of alcohol and ether, which was not the case with the true gun-cotton; and that on allowing the solvent to evaporate, a semi-transparent mass was left in which no trace of the structure of the original material remained. This solution was eminently adapted for forming thin films on glass plates; and as this was a great desideratum at that particular period for photographic purposes, the new material began to be manufactured on a fairly large scale. It was soon found that, by slight modifications in the method of manufacture, and by loading it with various foreign materials, excellent imitations of amber, ivory and tortoiseshell could be obtained, with the result that the manufacture of collodion has now attained very considerable importance.

One of the most beautiful applications of collodion is the manufacture from it of artificial silk. In the interesting, but little known, town of Besançon, the French inventor Chardone has established a large manufactory in which collodion, made by nitrating wood pulp, is dissolved in the smallest possible quantity of alcohol and ether; and the emulsion is then squeezed out under a pressure of 750 lbs. to the square inch through capillary glass tubes, the clear-way of which is less than one-hundredth of a millimetre. This enormous pressure is required to cause the material to flow evenly through the excessively small apertures. The filaments from ten to twelve of these tubes are then twisted and wound on to a bobbin, in a machine of the same character as is used for the spinning of silk fibre. The air of the room in which this operation is carried out is kept at a sufficiently high temperature to cause the instantaneous setting of the filaments, owing to the evaporation of the alcohol and ether; so that within three or four inches of the tube from which the material is issuing it has lost all stickiness, and may be twisted without cohesion between the threads. These have all the appearance of silk, but have one serious drawback that, being practically a low form of gun-cotton, they are excessively inflammable, and burn with a violence only a little removed from that of true gun-cotton. In order to overcome this trouble, the skeins of artificial silk are soaked in ammonic sulphide, which has the effect of what is termed "denitrating" them, and converting them once more into cellulose; so that, after washing and drying, the material

prepared is not more inflammable than an ordinary fabric. This material is capable of taking every shade that the dyer's art can impart to it, and forms a most beautiful and wonderful imitation of silk—lacking only to a slight degree the elasticity found in the original article.

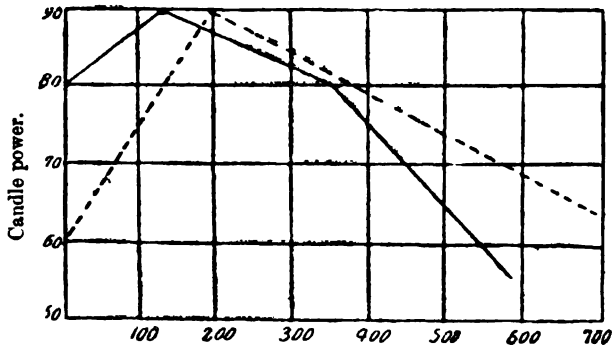
This extremely beautiful process was brought to perfection by Chardonet, and protected by him during the period which extended between 1886 and 1893; and in 1894, De Mare took out a patent for making incandescent filaments by charging collodion with metallic salts and oxides, squeezing into threads, weaving, and burning. In this patent, however, he makes no mention of denitrating the collodion filaments before burning, which would render it extremely difficult to make a mantle according to his patent. In 1895, Knöfler patented the manufacture and denitration of collodion threads or filaments loaded with oxides or salts; and in his first claim he mentions that the filaments may be "individual, or spun and eventually wrought or woven threads, which are made after the manner of the so-called artificial silk." Later on Plaissetty took out a patent which differs from Knöfler's only in that he uses glacial acetic acid as the solvent for his collodion cotton, and, instead of denitrating with ammonic sulphide, employs a solution of sulphide of lime, which, however, has the drawback of leaving a trace of lime as an impurity in the finished mantle.

Mantles made by such methods as those devised by Knöfler and Plaissetty are developments of the Clamond hood and not of the Auer mantle; the difference being that, whereas the Clamond class consists of filaments of even density made by squeezing a plastic material into rods or threads, which, after the binding material has been burnt off, leave a uniform mass of oxide, the Auer class consists of filaments having a dense central portion surrounded by a more or less spongy coating, due to the fact that the soaked fabric on burning-off leaves the oxides produced from the interior of the capillaries in a dense state, while the salt on the exterior of the cotton, in its conversion into oxide by heat, is rendered spongy by the escape through it of the gaseous products of the combustion of the cotton.

The physical effect of this on the mantle is that the Clamond class is harder than the Auer, and does not show the

same high incandescence until the surface of the filaments has become eroded by burning for a short period; the life of the Clamond class, however, when made of the same material as the Auer, is longer. For instance, two mantles, one made by the Knöfler and one by the Auer method so as to yield an ash containing 99 per cent. of thoria and 1 per cent. of ceria, would give curves of the following character :—

5 cubic feet of gas.



——— Welsbach. ------- Knöfler.

The total life of the Knöfler and Plaissetty mantles is probably one-third longer than that of the Auer mantle.

There seems to be every probability that mantles of the Knöfler and Plaissetty type will play an important part in incandescent lighting, as in Paris the Welsbach Company have acquired the patent rights of the process, and are introducing an innovation upon it. On taking a collodion mantle and heating it in a drying-oven for a certain length of time, considerable shrinkage takes place; and if this shrunk mantle is then put upon a burner and burnt off, the fabric rapidly moulds itself to the form of the flame with but little manipulative aid. For street lighting and for maintenance work, it would manifestly be a great convenience to do away altogether with the collodionising, which always to a certain extent impairs the light-giving power of the mantle.

Another new feature which has been introduced into mantles

of this class is to do away with the asbestos thread and loop, which has always been a weakness in the fabric, and make the strangulation at the top of the mantle by sewing it round with fibres of the same character as those of which the mantle itself is composed; this constricted annulus then resting upon a supporting ring, which is fixed as the ordinary support in the centre of the mantle. The asbestos thread has always weakened the top of the mantle, owing to the difference in the rate of contraction during burning off; and with a mantle merely resting on a supporting ring in this way, it is possible to get what really is an anti-vibrating arrangement, which materially enhances the life of the mantle for outside work.

The matter which I have brought before you has already occupied so much time that I do not propose to go into the question of burners. Many highly vaunted improvements have been introduced during the last two years; but they have all been based upon the idea first introduced by M. Bandsept, of getting the proper admixture of the maximum of air and gas to be burnt at the bottom of the burner, and perfecting and completing the mixture close to the mouth of the burner, where the combustion is to take place. In many cases, the increased luminosity given by such burners is really due to the length of tube, the increase of which acts in the same way as increase in gas pressure. These improved burners have shown themselves to be extremely variable; for while, with carefully adjusted samples and careful manipulations in the laboratory, it has been possible to get as much as 25 candles per cubic foot of gas with a properly prepared Welsbach mantle, in practice on a big scale the duty given is quite as often 17 candles or less. The old Bandsept burner, when properly made, is still as good as, or better than, the new ones.

DISCUSSION.

The PRESIDENT: I am sure we are all deeply indebted to Professor Lewes for that most interesting lecture, one of the most interesting we could possibly have listened to. We are also deeply indebted to M. Plaissetty for having taken the trouble to come over to this country to bring us the beautiful mantles we have seen. I have personally great pleasure in

proposing a vote of thanks to M. Plaissetty. If there is any question you would like to ask Prof. Lewes, I think I may safely say he will be pleased to answer.

The PRESIDENT: Well, gentlemen, as we have no questions to put, I ask you to show your appreciation of the lecture by according with acclamation a hearty vote of thanks to the able lecturer.

THE PRACTICAL WORKING OF CARBURETTED WATER GAS.

By CHARLES F. BOTLEY.

Several valuable and interesting papers on carburetted water gas have been presented in recent years to this Institution, but the importance of the subject to the gas profession probably renders excuse unnecessary for again bringing it forward.

The manufacture of water gas affords many opportunities for investigation, and, without doubt, has great possibilities. The few remarks the Author has the honour of submitting to-day are the result of his experience at Hastings in the responsible supervision and occasional actual working of a plant. It is desirable to point out, that in the year 1895 the matter of enrichment became an important question at Hastings, owing to the price of cannel, &c.

At first, as was only natural from previous experience of those concerned, oil gas manufacture (Peebles process) was very much favoured, but finally, owing chiefly to the advantages offered by disposal of surplus coke, the wider range of available oils, the addition to the productive power of the works and rapid production in emergency, carburetted water gas was adopted, and in the result the Author feels sure that his father, Mr. C. E. Botley, has had every reason to be glad of his decision.

The plant, as originally erected by the contractors, under the supervision of the Author, as the engineering assistant of the company, comprised two sets of generators, carburetters, superheaters, scrubbers and washers, of a nominal capacity per diem of 375,000 cubic feet each. The other plant consisted of a water condenser, 30,000 cubic feet per hour meter, 30,000 cubic feet relief gas-holder in steel tank, separator, two circulating water pumps, two oil pumps, one tar pump, two oil

meters, two high-speed double cylinder vertical engines, driving the fans by means of belting, each fan and engine being equivalent to the two sets working simultaneously, in view of extensions. There are six oil tanks, 24 by 9 feet diameter, of a working storage capacity of 50,000 gallons. This subdivision of storage may appear curious, but it was necessary to meet the circumstances of the position, &c. Above the oil stores the circulating water tank is placed, divided into two partitions for boiler feed and supply to washers, scrubbers, &c.

In conjunction with the water gas plant, a modern high-pressure steam installation, 110 lbs. per square inch working pressure, was put down, comprising two 24 by 7 feet Lancashire boilers, consuming either coke, breeze, tar or other refuse, and fitted with Green's economiser, exhaust steam water heater and chimney. Of course feed pumps, tar feed tank, &c., are included, and these boilers supply steam to the whole works. The cost of the plant, as just described, has been about 10,000*l.*, existing buildings, altered to suit, being used to accommodate the apparatus. The original plant has been considerably altered and added to, as will be referred to in due course.

It will be convenient to deal with the manufacture in the various stages of the process. Thus, to start with the production, or generation. The generator plays a vital part in the manufacture, and is subject to more wear and tear in comparison with other parts of the apparatus. At Hastings the usual fuel bed is 4 ft. 10 in. diameter by 9 feet deep when making an average of 20,000 cubic feet per hour, as against 15,000 to 16,000, the rated capacity of the sets. In lieu of a better arrangement, the coke at present has to be delivered in barrows to a small space provided near the plant, where the charging barrows are filled, and then hoisted, by means of a steam lift, to the operating floor. The original lift has been entirely remodelled, but although the working is now satisfactory the waste of steam is considerable, and when possible an hydraulic lift would be preferable. Some coke (10 tons or so) is always kept on the stage for emergency. Dry coke is very necessary, or retort carbon can be used, and the better the fuel the better the working. The blowers and engines claim attention with the generators, and should always be started (after the plant has been standing for a short period) before anything else is done, for under some circumstances

t is possible for gas to gather in the blast main,* and, as a further precaution, they should not be stopped more than two minutes occasionally for examination during working. When the blowers are stopped the relief-valves on the blast main can be opened.

The proper, or most suitable, amount of blast is of importance. It must be enough, but anything beyond will cause waste of fuel, excessive burning of generator lining, heavy clinkering and much coke dust deposited in the neighbourhood. The Author has found a blast pressure of 16 to 17 inches of water ample. This will give some 10 or 11 inches under the fire-grate. The speed of the fans or blowers is reduced from about 1700 to 1800 revolutions per minute during the "blowing up" to some 500 or 600 during the gas-making. This of course saves steam, answers well, and is accomplished by the operator closing, by means of suitable gear, the main supply of steam, and leaving only a by-pass. The engines being vertical, and of high speed (280 to 300 revolutions per minute), require constant careful attention, and, especially when the speed is varied, precautions must be taken that the condensed water in the cylinders can always escape freely; likewise, the governor gear must always be kept in good order. These engines drive the fans by belting, and for the high speed required it is very desirable to have light endless belts. Such will be found in the Balata make, but these must be protected from oil or resin. The original generator fire-grates did not answer, owing to the heat causing them to sink, and in sinking bringing the fire-bars so close together as to block the air-ways. New grates were adopted, having two specially designed cross bearers instead of one, but even those show signs of sinking. The size of the bars is 3 inches by 2 inches flat, which have proved satisfactory, although a taper section would allow the ashes to escape more quickly, and probably a mechanically operated grate would be an advantage. Careful clinkering is very essential, and is done generally about every five hours, or once for every 100,000 cubic feet made, which has been found to enable remarkable uniformity in make per run to be attained. At each clinkering there is of course a considerable amount of material removed from the generator. When

* An accident from neglect of this precaution has occurred, resulting in the destruction of a fan, &c.

working day shifts only, this averages 8½ cwt. per clinkering, and is composed of 2½ cwt. of clinker and 6 cwt. of coke and breeze. The latter are used for boiler fuel, and are not included in the figures given for fuel. Dry high-pressure steam should be available at the generator, 100 lbs. per square inch usually, and 90 lbs. as a minimum. A good steam trap is therefore an advantage on each generator steam pipe, but, despite these precautions, No. 2 set is at a disadvantage as regards No. 1 in the matter of CO_2 produced, it being farther from the steam main. The matter of the amount and distribution of steam in the generator is an interesting one. Other conditions being normal, the make per run will vary tremendously with a *given* opening of the steam cock. This is owing to the condition of the fire, but experience soon decides the proper or best quantity. It has, however, been found more satisfactory not to interfere, under ordinary circumstances, with the steam cock, and many times it has been noted that, when the steam has been on in excess, the valve has been turned back without reducing the make per run, but with a reduction in the amount of CO_2. Excess steam means unnecessary expenditure of fuel, and, as a result, makes a lot of clinker. The coke per 1000 cubic feet made averages about 44 lbs., but from this has to be deducted the residue coke from clinkering, which, as already stated, is used under the boiler. The amount of coke used will vary with the percentage of CO_2; thus, if it is desired to reduce the CO_2 to a minimum, more coke is necessary.

The percentage of CO_2 in the crude gas at Hastings averages under 3 with No. 1 set, and under 4 with No. 2 set, which is probably satisfactory. Generally three tests for CO_2 per day shift are made by means of the Cooper's Tube. (It may be pointed out that unless fresh water is used each time with this test, the results are not reliable.) The average length of time for the blow is four minutes, with a minute extra for every cwt. of coke charged into generator; a clear, clean fire being quite as necessary for gas-making as to ensure a good supply of producer gas for the heating up of the other vessels. In the ordinary way the producer gas will ignite immediately the blast on the carburetter is opened, but after every three or four runs, when either three or six cwt. of coke has been on, the ignition will be correspondingly delayed.

In this matter of blowing up or heating the vessels of the set, the question of labour can be considered. It is very desirable to select sober and intelligent workmen as operators, as a skilful operator can save much by properly regulating the production of producer gas and its combustion by the introduction of the secondary air at the proper point or points, and amongst other things, obviate much unnecessary "roaring" at the stack valve. Seven minutes' make has been adopted as the most satisfactory, longer and shorter periods having been carefully tried. Up and down runs for making are worked in the proportion of two to one, but the down runs are dispensed with some time prior to clinkering, to assist that operation. The valves which are used in this connection require constant attention whilst the set is at work, and should be examined internally when the set is standing off as spare. For operating them a rigid method of connection is advisable. Likewise, the down gas-pipe may become partly blocked with dust, and should be cleared periodically. Leaky steam cocks, or a defective blast valve will cause much trouble on a generator until the defect has been discovered and remedied. Other little troubles with ash-pan door, clinkering doors, &c., are best met by keeping spare ones ready. Climbing clinker has not given any trouble, but this may be due to the fact that it is a rule to run the fire down and clear the same right out every two or three weeks, when opportunity is taken to examine the grate, linings, &c.

The wear and tear of the generator linings is, perhaps, not satisfactory, and trouble with local burning away has been experienced, and for every twenty-five or thirty millions made, it is found desirable to renew the bottom interior ring of lining at a cost of labour and materials of about 10*l*. This is done as soon as a set is shut down in order to be ready.

The carburetters installed were of the usual type, with oil sprayers designed to spread the oil as much as possible. From the outset this plan of injecting oil on to heated bricks was looked upon as a very crude and unscientific method, and, rightly or wrongly, the following defects were attributed to the method. It was difficult to keep the sprayers in clean and efficient condition, even though they were regularly examined, and in case of a block necessitating the removal of the sprayer, much time was lost. The oil being forced by the pump through the meter and the heater, did not give a continuous supply or

spread the oil over the whole area of the chequer work, causing excessive cooling of the same, and incomplete gasification of the oil. The cooling of the carburetter naturally needed the expenditure of extra fuel in the generator, and often caused the superheater to get unduly heated. The oil had to be shut off a certain time, according to circumstances, before the end of each run, and after the blast on generator had been opened a further period had to be allowed so that the stack valve could be opened without oil vapour being lost, or presumably lost, and it is a doubtful point whether this "blowing over" gas is of any permanent value. Ignition of the producer gas at the top of carburetter was generally delayed, and frequently caught with a "pop," or slight explosion. During the blowing up, the last traces of oil from the previous run would be observed burning on the bricks, and when the plant was shut down from shift to shift, oil vapour used to burn for some time at the stack valve. Surely this was all loss of oil, and, in addition, the carburetter would become very dirty from carbonaceous deposits, and the top bricks of chequer work converted into practically pieces of carbon, which only gave a false heat when heated up. The carburetted water gas made at the time in question, appeared to be of a very oily character, which tested well at the plant, but gave considerable deposits, and did not yield anything like its proper enrichment value, but of course it is very possible the plant was not worked as well then, when it was comparatively new to those concerned, as is the case now. However, it was deemed worth while making some endeavour to improve the carburetters, and this is briefly what has been done in this direction.

The flat top has been replaced by one of conical shape, extending about 3 ft. 11 in. above the floor, the angle of this top being the same as the interior of the crown lining, with the object of being able to distribute the oil over the whole area of the chequer work. The top flange measures 7 feet from the top of the chequer work, leaving a space, roughly, of 40 feet cubical contents for expansion and other purposes. A less depth of chequer work has been tried in order to secure a larger expansion chamber, but it was not successful, as all the oil was not volatilised. A step is fitted on one side in order to be able to see in the top sight-cock, but the glass by which the operator makes his observations is fixed close by the blast valve at an

angle, so that he can see when ignition has taken place, any shock or "pop" from an early ignition being much less marked since this top has been used. This space, of course, also becomes filled with gas during a run, and although means were originally provided to remove this, it has not been found to be of any consequence beyond now and then obscuring the sight glass. To overcome the objection of injecting oil on to the heated bricks, it is now put in by means of an atomiser operated by either steam, air or gas. This atomiser converts the oil to the form of fog, with, perhaps sometimes a little oil *dust*, or very fine drops. Oil in this form is obviously in a ready condition for volatilisation, and mixing as it does with the very hot water gas coming from the generator, it is, doubtless, partly, thereby rendered gaseous, the heavier portions of the oil being converted in the passage through the chequer work. It is well known that the volume of gas from the generator during a run decreases after the second minute, and thus it is desirable to reduce the oil in proportion. This point has apparently been already recognised in other plants, as also the necessity for thoroughly distributing the oil, but with the carburetter described, the oil is put in continuously (not intermittently, as with a pump) in a decreasing amount coincident with the reduction in the volume of gas coming from generator. It would probably take too long to describe exactly how this is accomplished, but it may be said that the oil is forced by way of the meters into a reservoir containing compressed air or gas or steam at 50 lbs. per square inch, either through the oil heaters or not, as desired; thus the supply of oil to the carburetter is to this extent independent of the pumps. In the case of the atomising force being gas or air, it is compressed and stored at 125 lbs. per square inch, and used at 50 lbs. per square inch and under, the compressor running at a constant speed regulated according to circumstances. Air has been used on account of safety since April 1898. Steam, when used, is taken from the main pipe through a reducing valve into a small reservoir, but the condensed water is apt to become a nuisance.

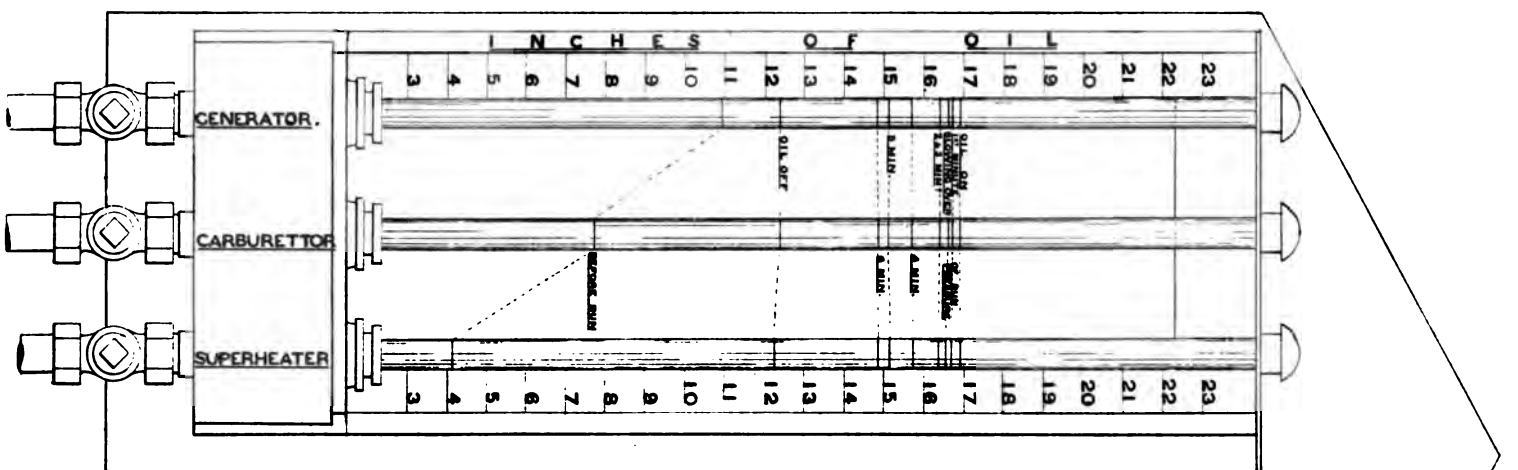
Air and oil have to be supplied to each atomiser, but these are readily disconnected, and it is easy to remove an atomiser, renew or change the nozzle, and replace within fifteen minutes. The nozzles are made in various sizes, according to illuminating power required, and last a long time. The difference in the

nozzles is mainly in the size of the holes, and a higher candle feet value for oil is obtained with a No. 1 nozzle (finest holes) than with other sizes. Each atomiser is designed for working with air- and oil-cocks full open, but there is a certain margin possible, for by using the air-cock partly closed, the amount of oil passed is increased. This practice, however, is not recommended, as, if carried too far, it impairs the efficiency of the apparatus. In many ways this alteration has (compared with previous results obtained) proved successful, a saving of oil being effected, and a more permanent gas of uniform quality produced. During an ordinary run, the pressure gauges of the generator, carburetter and superheater are all on a level (*see diagram*), and the stack valve is usually opened without the escape of oil vapours within thirty-five seconds of the oil being shut off. There has not been any trouble with carbon in the carburetter, which keeps very clean, except for dust coming over from the generator, and although hitherto this has been got over by removing the brick chequer work occasionally, it will probably be better to blow this dust out in some way in future. New chequer work for a time absorbs some of the oil vapours, and the lining of the carburettor and the pipes leading into same from generator, require attention occasionally, and it is advisable to have the covers off at the base of the vessel each time the set is shut down for changing over, to prevent dust blocking. Likewise, the blast, or secondary air valve on carburettor has to be remembered. In working, the heat of carburettor should be carefully watched, since the heats required for different oils vary considerably. Too high a heat means the production of lampblack or carbon, and too low a heat, excessive production of tar, with semi-permanent gas. At Tottenham it is reported that too high a heat in the carburetter resulted on one occasion in naphthalene trouble in the distribution, and the reason for this it would be interesting to know.

Coming now to the superheater, this is sometimes considered a superlative vessel. Theoretically it would appear that a gradual increase of heat from top of carburetter to top of superheater ought to be correct, but for volatilisation in practice this is difficult, for it would mean "banging" at the stack valve and other troubles. A "too hot" superheater is a great nuisance in water gas manufacture, but with care this can be avoided. Every set will have peculiarities, and for some reason

Diagram of Actual Pressures taken in connection with Run No. 20, April 12th, 1899.

Average Gas made per run, 5,024 c. ft. Average Oil used per run, 15·43 gallons.



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СУПЬОКИЙ
ПИЛ ОЬ

No. 1 set at Hastings has always been hotter than No. 2 in work, and especially with regard to the superheater. Oil vapour burning at the stack, too much blast on generator in blowing up, and leaving the set standing with generator top door open, are fertile sources of this trouble, and also, during clinkering, there is time for the superheater to get very hot, and therefore the operation should be promptly carried out. In regular work with uniform make the heat of the superheater is kept under control by the work done in the conversion of any oil vapour passing forward from carburettor. A hot superheater can be remedied in several ways, by regulating quantity of producer gas carefully, or by making short blows, and so cooling the carburetter that the gasification of a considerable amount of oil vapour has to be done in the superheater. It is a good plan to test the gasification of the oil at a test-cock on the superheater, and a brown stain, free from oil spots, on white paper in the last minute of the run is considered satisfactory.

Stack valves are apt to give trouble, especially when working with some tarry oils, but with a little perseverance the leakage can be reduced to a minimum, and it will be found advisable to clean the faces after the plant has been standing for a while, for then the tarry substance will have lost its sticky or gummy nature and be converted into carbon, which will scrape off. The centre pin of this valve may get brittle and break in course of time, so a spare one should be handy. No other trouble has been experienced, but the cover plates are occasionally removed to examine chequer work, and see that dust is not accumulating. With a clean set very little smell need be caused by the blowing up, beyond now and then a slightly sulphurous odour in the immediate neighbourhood, but the fine dust is apt to become a nuisance. A moderate blast presumably minimises this, and it is found advisable to clear the roof and gutters regularly, especially in very dry weather.

The outlet for gas from superheater to washer or back (down take) pipe requires cleaning every two or three weeks, and an examination even weekly is time well spent, for an unusual amount of carbon would at once indicate that the heat of the set had been too great for the oil. It is, however, important to distinguish between carbon as soot (the result of excessive heat) and the carbon which must of necessity form a coating to any pipe through which it passes under some pressure and at a high

temperature. Of this latter, about a bushel is removed at each cleaning. The oil heater coil is placed in the back pipe, and a slight coating of carbon to this is, doubtless, a valuable protection. As the back pipe seals in the washer on the ground floor, when cleaning care has to be exercised that no deposit falls and blocks the dip pipe. The washer, in order to prevent deposits in the bottom of same, has a useful scavenger arrangement which is operated from the stage, and a good supply of circulating water is also connected. The washer requires periodical cleaning, and when this is done, it is flooded with the lower part of the scrubber up to a certain level, as indicated by a pet-cock. By this means all gas is expelled from the washer, and no gas can come back owing to the water seal at base of scrubber. It is, however, important to see that the bottom valve of scrubber is sound, which can be done by means of the pet-cock already mentioned. In this operation it is unnecessary for the men to enter the apparatus in any way, a practice which should be strongly guarded against, for crude water gas is very apt to remain about for a long time. The liquid from the washer passes into a seal-cup, and hence by a 4-inch pipe to the separator. The seal of the washer is adjustable, and a good stream of liquor should be kept running through the seal-pot, where it can be observed both as regards character and quantity. For night work electric light is provided at this point, as a naked light would be dangerous.

From the top of the washer the gas enters the bottom of the scrubber, a rectangular vessel containing wooden grids, down through which a stream of circulating water is kept running. The water enters the distributing arrangement by way of a pipe syphon, and has been always used in regular quantities. The character of this liquid is very important, for the presence of too much tarry matter will certainly cause trouble by blocking. A supplementary water supply is connected to each scrubber, and all liquid escapes by way of the washer and its seal-pot to the separator. The temperature of the gas at the outlet bend of the scrubber is at present the only guide to the heat of the set, and, as observed during a run, rises to about 172° Fahr. with ordinary oils. Some reliable and practical method of being able to ascertain the temperature of the vessels of the set would be a great advantage, instead of having to trust to the eye and the heat of the gas.

Excessive washing or scrubbing of the gas should be avoided, and, indeed, it has been proposed to work the scrubber practically dry, but so far time has not permitted any careful investigations on the point.

From the scrubber the gas passes to the water-tube condenser, which is under cover, and was designed to serve both sets working simultaneously, if desired. A by-pass main is provided, as also a tar seal-pot, communicating with the tar division of the separator. This seal-pot has a water supply laid on, and is periodically inspected, but has given no trouble, the tar keeping very fluid. It is endeavoured to keep the condenser at 60° Fahr. on the outlet, but during the hot weather this cannot be done, even though well (very cold) water is pumped through its tubes to the overhead boiler-feed and cooling tank. Experience in this direction goes to show that a water-condenser is not the most suitable for water gas, and a plain 12-inch pipe condenser has been erected to improve matters. This introduces frictional condensation, and effects a reduction of about 5 to 10 degress in temperature, according to weather, but increases the pressure about three-quarters of an inch. A small amount of oily tar is deposited therein.

As already mentioned, the circulating water from the washers and scrubbers, and tar from condensers, has to be dealt with in the separator, and in this connection most of the troubles of water gas manufacture will arise. The separator now concerned is a steel vessel in a brick and concrete tank, and covered in with timber to avoid annoyance to the neighbours in the way of smells, the tar being very pungent. It is divided transversely with partitions, and has strainers and an inclined bottom, in order for the tar to gravitate to the proper compartment. The separation, so far, has not been satisfactory, but it is not in any way an easy matter. For one thing, the apparatus is evidently too small, and is kept too much agitated when the plant is working day and night. Better results are obtained when only one shift is worked, allowing the liquid to stand some ten or twelve hours, and in view of this it is intended to provide another tank into which the mixture can be pumped to separate. From this proposed additional separator a new pump will be fixed, to raise the tar up to the siding level for sending away. Coal gas liquor has been tried to assist separation without much

success, but it was noted that when first the cooling water from the jacket of the air-compressor (used for improved carburetter) was added to the hot effluent from the washer-seals, the separation was better, but as this produced too much waste water it has been discontinued.

It should be noted that the liquid from the syphons of the plant is put into the separator, thereby adding a considerable amount of water, with some oil. Such tar as is produced is either burnt (not very successfully, owing to the contained water), thrown upon the coals, or sent away to the contractors who take the ordinary tar. The oily tar is not an acquisition in the retort house, although it undoubtedly does improve the illuminating power, and that sent away has contained 50 to 60 per cent. of water, which should be remembered in comparing the figures given under the liquor made. The percentage of water in water gas tar varies in a very remarkable degree, and it is a point to which very careful attention will be given as time permits, for it is obviously most important to convert the oil into permanent gas, and not oily tar. The amount of tar a given oil produces under the best conditions of heat, &c., has to be considered in comparing the relative values of different oils. The water circulating through separator, washers, &c., has to be pumped at very high temperatures (about 170° Fahr.), and hence troubles will arise. This water can be cooled somewhat by being passed through a coil in the feed-water tank on the way to its compartment of the same overhead tank, but, notwithstanding, very considerable wear and tear on the pumps has been experienced, the liquor attacking cast iron and steel with great vigour. The amount of water or liquor "makes up" somewhat, and the surplus is disposed of by evaporation under the retort furnace ash-pans, but care has to be exercised to see that the liquor is free from oil, and only specially appointed men are allowed to deal with it.

For better separation a centrifugal machine has been suggested, and this will, perhaps, have to be eventually tried. It is part of the engine-man's duty to look to the separator, and he has to see that there is a return flow from the supply tank, an operation at night-time which should not be done with a naked light, and again electricity is made use of. For use in the unhappy event of fire coal-gas liquor is connected close at hand, and a supply of sand is also kept ready.

The gas from the condensers passes direct into the relief holder, the contents of which are conveniently shown on an indicator in the engine-room. When first the plant was started much oil collected in the holder, and on one occasion a quantity escaped by way of the water overflow pipe, and caused many complaints in the town. Steps were at once taken to prevent this again occurring, but very little oil appears to be so deposited now.

Originally the crude water gas was drawn from the holder through the meter by the coal gas exhausters, some distance away, and added to the coal gas at the outlet of the condenser, or at a point on the foul main from No. 1 retort-house. This plan was convenient, but it was bad for the illuminating power, and caused other troubles, so that now a new exhauster in the engine-room of the plant draws the gas from the relief holder and forces it through the purifiers.

As will be understood from the preceding paragraph, the water gas used to be purified in conjunction with the coal gas, and in the same boxes, but as the Hastings Gas Company has to work under the Sulphur Clauses this plan was not a success. The oxide-boxes got very oily, resulting in their giving pressure, and the extra CO_2 (carbonic acid) in the water gas quite upset the lime-boxes on several occasions, although it should be understood that the purification was really carried out for short periods successfully, working this way. Once during the time the "sulphur" went up to a very high figure, which was found to be due to sulphurous acid, evidently driven off in the oxide-boxes (which were not often used afterwards). For the past eighteen months, or so, the purification has been carried out in part near the plant itself, two old 20-foot purifiers being made use of. From these the gas passes into the outlet main of the coal gas lime-boxes, and the mixed gases are dealt with in the catch-boxes Nos. 7, 8 and 9; No. 7 being lime and Nos. 8 and 9 oxide. It is not easy to remove the last traces of H_2S from the mixed gas, especially under some conditions, and although the boxes may give a clean lead-paper test, a slight trace may be obtained in a twenty-four hours' test. Some oil used to be deposited in this mixing main before the improved carburetter was adopted, but now the condensation from the syphons thereon is only slightly oily. It is a curious thing, in view of the nature of the gas, that water gas should carry so

much aqueous vapour, but that this is so can be readily demonstrated by testing with slate on the outlets of coal and water gas lime-boxes respectively. If this water vapour goes forward in the mixed gas, as is probable, and comes down with change of temperature, it would be a means of assisting the deposition of naphthalene, if present in the coal gas. For purification, both lime and oxide have been tried, separately and conjointly. With the purifiers trouble at once arose, owing to oil being deposited on the bottom layers of the material therein, and to overcome this, in some measure, coke is introduced into the space below the first row of grids with satisfactory results. The coke is changed once or twice a year, although, at the present time, comparatively little oily matter reaches the purifiers, which are used in rotation.

Oxide appears to have, and especially so when new, a very marked detrimental effect on carburetted water gas, and becomes sticky with oil, which, however, disappears to some extent during revivification in the atmosphere. Air can of course be drawn in with the gas to assist matters, and this was one point considered to be in favour of using air for atomising the oil in the improved carburetter. (How much of the two per cent. of air passes into the purifiers is a doubtful point, under investigation.)

Generally speaking, when oxide is used for purification, the CO_2 in the gas would be ignored, the volume of purified gas being benefited to the amount of the same. At Hastings, however, oil, owing mainly to transport, is very expensive, and may be considered at present time at no less than 4*d.* per gallon. Thus it becomes a question which is the more economical plan, to use more oil, or remove the CO_2, and the latter, having been found to be advisable, lime has, as a rule, been used.

Such investigations on the point as it has been possible to make up to the present time, tend to show that the illuminating power of the carburetted water gas is diminished by ¾ to 1 candle for every 1 per cent. of CO_2 therein. Thus, as lime purification for water gas costs from 2½ to 3 times as much as for coal gas (say, 1½*d.* per 1000 cubic feet at Hastings), it is obvious from a rough calculation that it is cheaper to purify from, than enrich to compensate for CO_2, for under most favourable circumstances the illuminating power would be reduced

3 candles by the CO_2, and oil to compensate would cost 2*d.* (against 1½*d.*), added to which there are other practical difficulties in raising the enrichment to the necessary extent.

Lime in one box and oxide in the other has been tried, but as the boxes have to be worked in rotation, this method was not satisfactory. In full work on an average each of the two limes has to be changed once a week and are run until the CO_2 on the outlet has reached 0·4 or 0·5 per cent. and the H_2S is quite strong. These impurities are further dealt with at Nos. 7, 8 and 9 boxes already mentioned. CO_2 and H_2S going into a lime box cause, owing to the chemical reactions, great rise of temperature. This is very undesirable, and especially in summer time, when after the temperature of the gas has been reduced by the condensers, it is raised again by the purifiers, and it is possible another plain condenser, or rather cooler, will have to be erected on the outlet of the purifiers. The two additional 30-foot purifiers now being erected may, however, be of some benefit in this connection. Experience will decide the best plan of working, but probably it will be an oxide and a lime alternately, for the connections are designed (see drawing) with a view to the four purifiers being worked in rotation, either Nos. 1 and 2 first, and Nos. 3 and 4 last, or *vice versa.*

It is hoped to reduce the cost of purification by using some oxide as well as lime, and relieve the other purifiers Nos. 7, 8 and 9 of work they have hitherto been called upon to perform. The disposal of the spent lime has to be considered, for it will always be slightly affected with oil, and although no serious difficulty on this account has been so far experienced, it is another inducement to reduce the amount of lime to a minimum.

Changing carburetted water gas purifiers requires considerable care, if nuisance is to be avoided, which is not always easy when the neighbours watch the operation from their bedroom windows, a remark, perhaps, those present who know the Hastings Gas Works can readily appreciate.

It is now the practice to allow a box that is to be changed to stand off some time previous to the cover being raised with the air-plug open, and air can be forced through by the fans. (It is unwise to have a permanent connection for this operation, as gas might get back into the fans, which it should be remem-

bered are in direct communication with the generators.) By such means the spent lime cools, and can be removed without much trouble, except in windy weather, when the lime, being so dry, it flies about, and the men have to wear eye-protectors.

It will probably be agreed that the success or otherwise of a carburetted water gas plant of any kind, depends greatly upon how it is managed, and this being recognised, the importance of skilled supervision becomes evident. The uniformity of results obtained may also in some measure be taken as a criterion of the efficiency of the supervision, for all practically acquainted with this manufacture will appreciate how difficult of accomplishment this really is, and particularly so under some conditions. In this connection it may be interesting to give a copy of an actual working (operator's) sheet with the corresponding engine-room sheet. As judged by Hastings practice, this is a good sheet, some, of course, being better, and some worse. This particular one has been selected since a Member of this Institution actually saw the plant at work on the day in question. Primarily intended for the enrichment of the coal gas, the water gas plant is worked accordingly, the illuminating power made being regulated as desired to give 15¾ to 16 (15 is the standard) candles on the mixed gas at the meter, where it is tested hourly in preparation for the night consumption. This plan of testing entails considerable work, but the results are most satisfactory. For about five months of the year a night and day shift (10 hours each) are worked, but a day shift only in the other seven months. The ordinary shifts allow about 20 per cent. margin in case of emergencies and repairs, but doubtless it may be said that the plant under these circumstances is not worked to the best advantage, which is admitted so far as results are concerned. The local circumstances, however, justify the arrangements stated, and indeed, this last winter coke has been so short that the quantity used in the plant could have been easily disposed of at a good price. The two hours' interval between shift and shift in winter has not been found to be of any practical consequence, but it is otherwise with the 12 or 14 hours' interval in summer. The greater part of the testing having to be done during the daytime, care has to be taken that returns for the night shifts do not influence the results obtained, and this is done by keeping the oil used per 1000 cubic feet as near as possible to the same figure as on the day shift.

(C. W.)—OIL GAS PLANT.

Engine-room Sheet.

Date, 7th day of February, 1899. Day Shift. Man, T. Mills.

Hour.	Index of Meter.	Made.	Stock.	Meter Temperature.	Condensers.	
					Indoor.	Outdoor.
6 a.m.	19,603	..	3000	..	..	..
7 „	..	..	..	..	..	..
8 „	19,628	25	..	71	56	..
9 „	19,653	25	..	72	56	..
10 „	19,670	17	..	72	58	..
11 „	19,690	20	..	71	58	..
12 noon.	19,712	22	..	72	58	..
1 p.m.	19,733	21	..	72	58	..
2 „	19,754	21	..	73	60	..
3 „	19,777	23	..	73	60	..
4 „	19,801	24	..	74	60	..
5 „	19,805	4	..	..	..	..
6 „	..	..	..	..	..	..
		202				

Oil received—
Put in No. Tank. Measurement—
Kind—
Oil used—
Out of No. 5 Tank, from 10½ inches. Measurement—3½ inches.
Kind—American.
Remarks, *re* Oil—
Tar made—5 Barrels (200 Gallons).
Water made—6 Barrels (240 Gallons).
Level of Separator—from 6 inches to 2 inches.
Air Meter—End of Shift .. 6083
Beginning of Shift 6038
Used 4500
Repairs done or required—
Purifiers changed—

HASTINGS AND ST. LEONARDS GAS WORKS.

Sheet No.
Date—7th Feb.
Shift—Day.
No. of Generator—1.

Gas Meter Index.
At end of Shift—19,805.
At beginning of Shift—19,603.
Total Gas made—202.

No. of Run.	Time Blast turned on.		Duration of Blast.	Time Steam turned on.		Duration of Run.	Coke charged into Generator.	Oil used per Run.	Gas made per Run.
	h.	m.	mins.	h.	m.	mins.	cwt.	galls.	cub. feet.
1	6	25	6	6	31	7	6	..	..
2	6	38	9	6	52	7	6	..	..
3	6	59	4	7	3	7	..	..	..
4	7	10	4	7	14	7	..	15·00	4·750
5	7	21	10	7	31	7	6	..	..
6	7	38	4	7	42	7	..	..	..
7	7	49	5	7	54	7	..	..	..
8	8	1	10	8	11	7	6	..	..
9	8	18	4	8	22	7	..	..	..
10	8	29	4	8	33	7	..	..	..
11	8	40	10	8	50	7	6	..	..
12	8	57	4	9	1	7	..	..	5·000
13	9	8	4	9	12	7	..	..	..
14	9	19	10	9	29	7	6	..	..
15	9	36	4	9	40	7	..	..	..
16	9	47	4	9	51	7	..	..	4·875
17	9	58	10	10	8	7	6	..	..
18	10	15	4	10	19	7	..	..	..
19	10	26	10	10	36	7	6	..	4·900
20	10	43	4	10	47	7	..	..	..
21	10	54	4	10	58	7	..	..	..
22	11	30	4	11	34	7	6	..	..
23	11	41	4	11	45	7	..	..	..
24	11	52	4	11	56	7	..	..	..
25	12	3	10	12	13	7	6	..	..
26	12	20	4	12	24	7	..	..	..
27	12	31	4	12	35	7	..	..	4·870
28	12	42	8	12	50	7	3	..	..
29	12	57	4	1	1	7	..	..	..
30	1	8	4	1	12	7	..	..	..
31	1	19	10	1	29	7	6	..	..
32	1	36	4	1	40	7	..	..	..
33	1	47	4	1	51	7	..	..	..
34	1	58	8	2	6	7	3	..	4·882
35	2	13	4	2	17	7	..	..	..
36	2	24	4	2	28	7	..	..	..
37	2	35	10	2	45	7	6	..	..
38	2	52	4	2	56	7	..	..	..
39	3	3	4	3	7	7	..	..	4·868
40	3	14	8	3	22	7	3	..	..
41	3	29	4	3	33	7	..	..	..
42	3	40	4	3	44	7	..	..	..
							81		

Total Gas made (uncorrected) .. 202,000 | Oil used, per 1000 .. galls. 3·09
Fuel used in Generator, per 1000 lbs. 44·91 | Gas made per run .. c. ft. 4809

American Oil.

C.W.G. PLANT. OPERATOR'S SHEET.

Oil Meter No. 2 Index.	Total Coke used.	Operator—J. Tanner.
At end of Shift—236,045. At beginning of Shift—235,419. Total Oil used—626.	Tons. 4 Cwt. 1	Atomiser No. 2. Repairs—Nil.

Oil per 1000.	Illuminating Power.	CO_2 (Purified Gas) per Cent.	CO_2 (Unpurified Gas) per cent.	Steam Pressure at Generator.	Temperature of Gas at Outlet of Scrubbers.	Time Apparatus not Running.	REMARKS.
galls.	candles.				deg. Faht.	mins.	
..	..	..	..	90	..	..	
..	..	..	3·4	98	..	5	Cleaning Top Valve.
..	..	..	..	95	162	..	Down Run.
3·15	..	..	..	98	..	..	
..	..	..	..	95	..	..	
..	..	..	..	98	..	..	"
..	..	..	..	98	..	..	
..	..	..	..	100	..	..	
..	..	..	..	100	..	..	"
..	..	..	..	98	..	..	
..	..	..	..	100	..	..	
3·07	..	..	..	95	170	..	"
..	..	..	..	95	..	..	
..	..	..	3·2	100	..	..	
..	20·30	c.	..	96	..	..	"
3·08	..	..	..	95	..	..	
..	..	..	..	96	..	..	
..	..	..	..	100	..	..	
3·04	..	..	..	100	..	..	
..	..	..	..	98	..	..	
..	..	..	..	95	170	..	
..	..	..	..	95	..	25	Clinkering Fire.
..	..	..	..	95	..	..	Down Run.
..	..	..	..	97	..	..	
..	20·53	..	..	96	..	..	
..	20·91	N. Ph.	..	100	..	..	"
3·06	..	..	..	93	..	..	
..	..	..	..	95	..	..	
..	..	..	..	93	170	..	"
..	..	..	..	95	..	..	
..	..	..	..	100	..	..	
..	..	..	..	100	..	..	"
..	..	..	..	95	..	..	
3·06	..	..	..	96	..	..	
..	..	..	..	95	..	..	"
..	..	..	..	93	..	..	
..	..	..	..	98	..	..	
..	..	..	3·4	94	172	..	"
3·06	20·59	..	..	95	..	..	
..	20·58	N. Ph.	..	98	..	..	
..	..	·4	..	100	..	..	"
..	..	..	..	100	..	..	

Illuminating Power .. candles 20·58 | Candles per gallon .. .. .. 6·64
CO_2 .. .. per cent. 3·33 | " " " per 1000 1328

The two ordinary shifts produce gas equal to an average of five coal gas retort beds (14 or 15 men), and the reserve is equal to another retort bed. This is, of course, an important aspect of the matter, and the value of the plant was strikingly illustrated in the recent spell of cold weather in March. Twelve retort beds were in use, and the plant was working long (12 hours) day shifts, with a good stock of gas in hand, but with snow on the ground the consumption went up by leaps and bounds, and the position would have been critical ere three or four retort beds could have been got into work and men found. As it was the plant was worked full until the crisis was over. It was during this period that gas was sent out containing upwards of 36 per cent. carburetted water gas, the highest reached as 33⅓ per cent. of the daily maximum make is all that is usually desired.

It is preferred to supply coal gas from down to within an hour or so of sunset, and coal gas enriched with carburetted water gas during the lighting hours, a plan which can be readily carried out, except just at midwinter, when the gas will be the same practically throughout the 24 hours. In this way the consumers get good illuminating power when really required, and water gas at Hastings has enabled the candle power to be maintained in a way never attainable before, and the sulphur compounds to be reduced to a minimum. No trouble of any serious kind has been experienced beyond its having been found desirable to increase the pressures at the works, to overcome the sluggishness of the mixed gas, as compared with coal gas, and the difference in the day and night gas may affect gas engines, unless these have been adjusted accordingly.

At this time of the year, when the plant is only worked one shift, the percentage of water gas is not correctly represented by the percentage of the daily total gas made, for it is only added to the coal gas during the day for consumption the same night. In this way a considerable percentage might now and then be used, a point of importance in view of proposed restrictions on the amount of carbon monoxide or carbonic oxide (CO).

Thus, while in water gas for enriching purposes it is found most desirable to reduce the CO_2 to a minimum, it would be a positive disadvantage in regard to the CO if restrictions are

to be made, for CO_2 and CO vary, as 1 to 2 in the case of the reduction of CO_2 to CO.

Thus:—

$$\begin{aligned} CO_2 + C &= 2\,CO. \\ 44 + 12 &= 56. \\ 22{\cdot}32 \text{ vols.} &= 44{\cdot}64 \text{ vols.} \end{aligned}$$

If, therefore, the gas contains 4 per cent. of CO_2 and 30 per cent. CO, reducing the CO_2 to 2 per cent. increases the CO to 34 per cent.

When CO is burnt to CO_2, curiously enough there is not any alteration in volume, thus:—

$$2 \text{ vols. } CO + 1 \text{ vol. } O = 2 \text{ vols. } CO_2.$$

The volume of CO varies from 30 to 34 per cent. in purified water gas, as against, say, up to 9 per cent. in the coal gas. In view of these figures it will be evident how a limit of 12 per cent. CO would seriously interfere with arrangements which so far have been highly satisfactory to all concerned. A mixture of $66\frac{2}{3}$ per cent. of coal gas and $33\frac{1}{3}$ of water gas, as already described, would give $(66\frac{2}{3} \times 9 + 33\frac{1}{3} \times 30) = 16$ per cent. CO. This, too, is only an ordinary case, and has not any regard to emergencies. Testing for the amount of carbon monoxide is now a matter of importance, and even with probably the most convenient apparatus (Hempel's) takes considerable time, which is of consequence in medium size works, not large enough to employ an analyst entirely. Although other tests are talked of, the only general absorbent for CO now in use is a saturated solution of cuprous chloride ($Cu_2\,Cl_2$) in hydrochloric acid (HCl.), but this is rumoured to give high results. In the ordinary way of making the test the CO_2, SH_2 if present, have to be removed together with oxygen and illuminants before the CO, and investigations are, therefore, now being made with a view to ascertain whether it is not possible by the direct application to the gas of a suitable strength solution of cuprous chloride to absorb the CO in preference to the other constituents. Some of these are affected by a saturated solution (oxygen, acetylene and the ethylene group). So far it can only be said that 10 grams of cuprous chloride in one litre of hydrochloric acid results in a solution, which, when fresh, yields concordant results (if anything, giving results

slightly less than the actual) when used on purified carburetted water gas, as per results as under.

Date.	Absorption by Special Solution.	CO %, as shown by Ordinary Test.	Difference.	Remarks.
1899.				
March 29th	(a) 32·4 (b) 32·4	.. ..	.. ..	.. ..
April 10th	31·6	32·0	·4	..
„ 12th	32·6	32·6	Nil.	..
„ 13th	33·4	33·8	·4	..
„ 14th	32·0	32·4	·4	..

See Appendix IV., A and B, for other tests *re* carbon monoxide.

The labour on the plant is as follows. The operator in charge, who works the apparatus and looks after all on the stage, the coke lift and overhead circulating tank: he assists in the clinkering, and has definite instructions to report immediately any defect or abnormal circumstance in the working of the plant. The engine-room man is responsible for all on the ground-floor, with separator, oil supply, &c., and assists with coke supply and clinkering. The coke-man takes part in the clinkering, assists in keeping the plant clean, and brings the coke from the yard; he also removes the generator ashes and other fuel to the boiler house. Another man, from the coal-gas section, assists at clinkering, making four men at this operation. All the steam for the whole of the works comes from the same boilers, and it has been found, by careful measurements of the water used, that the proportion of steam required by the water gas plant is about one-third of the whole. It may be of interest to note that in full work this means about 6 gals. of water for 1000 cubic feet of water gas made. Calculated on a production of 200,000 cubic feet per shift, the cost of the labour just described for manufacture (including half the boiler-men's wages, not one-third) may be taken at 1*d.* per 1000 cubic feet. Similarly, the purification costs about ·33 of a penny (labour only). The heavy wear and tear has already been referred to, and a fitter is, practically, entirely engaged on the work. The average labour (including proportion of boiler repairs) may be considered as about ·33 of a penny per

1000 cubic feet. It is only fair to state that some wear and tear has hitherto been altogether exceptional, and is being remedied. The total recorded cost of material required for repairs and spare parts since the plant was started has been about 250*l.*, and 135,000,000 of gas having been made, this is equal to ·45*d.* per 1000 added to the labour; this is a total for wear and tear of ·78*d.* per 1000 cubic feet. The addition and alterations to the original plant have cost about 600*l.* (exclusive of new purifiers). The cost of supervision is not great, being undertaken by the existing staff. Careful supervision repays itself in many ways. Thus, a quarter of a gallon of oil per 1000 cubic feet inefficiently used, or more than necessary for the required enrichment, would mean a loss of 2*l.* 10*s.* in one shift at Hastings, an amount which would pay for a large amount of supervision and testing.

For comparisons between respective water gas plants to be of any real value it is most important for all the influencing conditions to be clearly shown.

Thus, the comparison will be influenced by :—

1. The size of the plant.
2. The purposes for which the plant is used (enrichment, &c.).
3. The kind of oil used.
4. The temperature at which the gas is measured.
5. The purification (whether CO_2 is eliminated).
6. The point and temperature at which the gas is tested.
7. The mode or standard of testing.
8. The amount of tar produced.

At Hastings, to summarise, the gas is corrected for temperature (the meter being unavoidably fixed in a very unsuitable position), is purified for CO_2, and is tested, under the most severe conditions, a considerable distance away. The standards employed are: (*a*) candles; (*b*) 16-candle pentane; and (*c*) Simmance's one-candle. The latter (*c*) gives somewhat higher results than the others. The water gas is consumed for the first test (*a*) in a Suggs's 20-candle standard argand, and for (*b*) and (*c*) tests, in a No. 1 London argand.

All the tests are corrected for temperature and pressure in the usual way, but this results in very funny figures at times.

Theoretically, of course, it is quite right, but there are times when gas made one day will test better the next, owing to the alteration in the tabular number, the gas evidently not exactly following the theoretical conditions. The temperature at which the gas is tested is under control usually, but no such control exists in regard to the atmospheric pressure, which varies to an extent not always perhaps conceived, with the resultant alteration in the tabular number for correction. The point at which the gas is tested is important. The connection to laboratory is taken off the water gas main just before its junction with the mixing main, and the gas is passed through a small oxide purifier to remove any traces of H_2S.

The endeavour is to produce as permanent a gas as possible, which the condition of the mixing main and purifiers Nos. 7, 8 and 9 is considered to prove is the case.

Thus, in the ordinary way, tests obtained on the separate photometer at the plant correspond practically with those recorded in the laboratory. If, however, the operator's test-light (the gas from outlet of condenser is passed through a small lime purifier on the stage for this light) is connected to the photometer at the plant, the results obtained are some ten per cent., and more, higher than the laboratory, and the difference used to be very much more marked. Ten per cent. added to the oil values given would materially improve the same. Possibly something might be done in the way of returning some partly purified coal or water gas to the condenser with advantage, and this point will be investigated.

There is, without doubt, an efficiency limit to the illuminating power of carburetted water gas, and obviously the more oil per run used the more work the set has to do. As to the limit, opinions will of course differ, but does it not vary according to the oil used? The gas is, after all, to a large extent a mechanical mixture, and part of the oil may be considered to be mechanically suspended by the non-illuminating constituents. If this is so it is only reasonable to suppose that such constituents can only carry a certain amount of oil properly, and any more will be deposited or wasted. The illuminating power required at Hastings varies from 18 to 22 candles, and it is preferred to have to make the lower quality. Both Russian and American oils have been used, as will be seen from the weekly summary of results. The American oil has given

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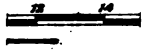

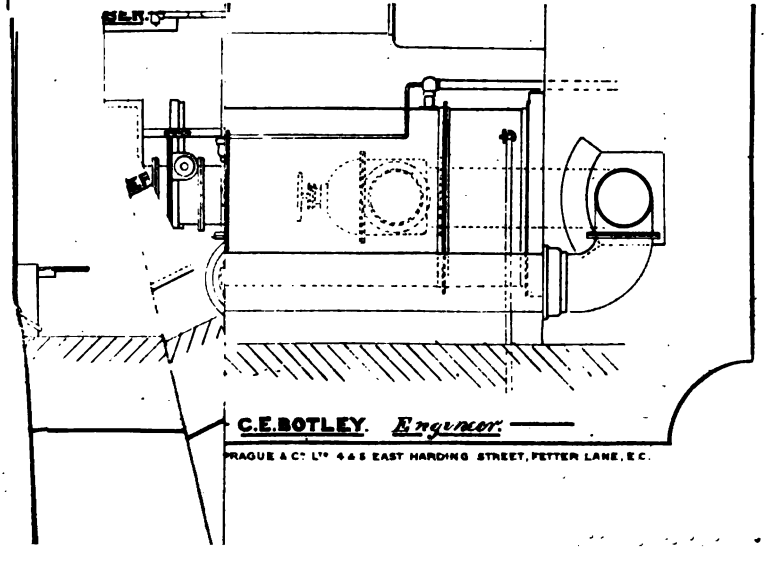
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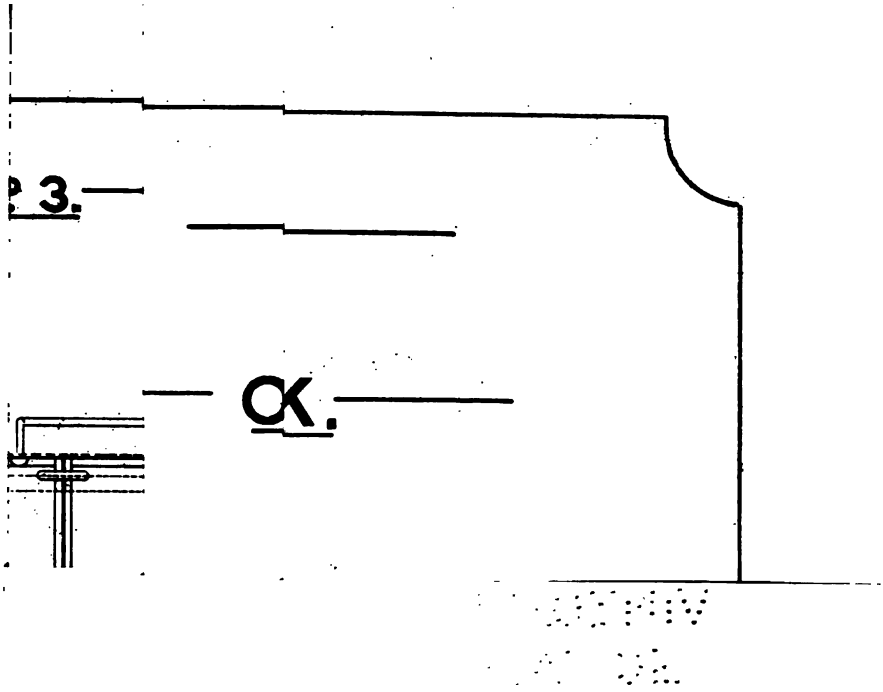
PRAGUE & Co. Ltd 4 & 5 EAST HARDING STREET, FETTER LANE, E.C.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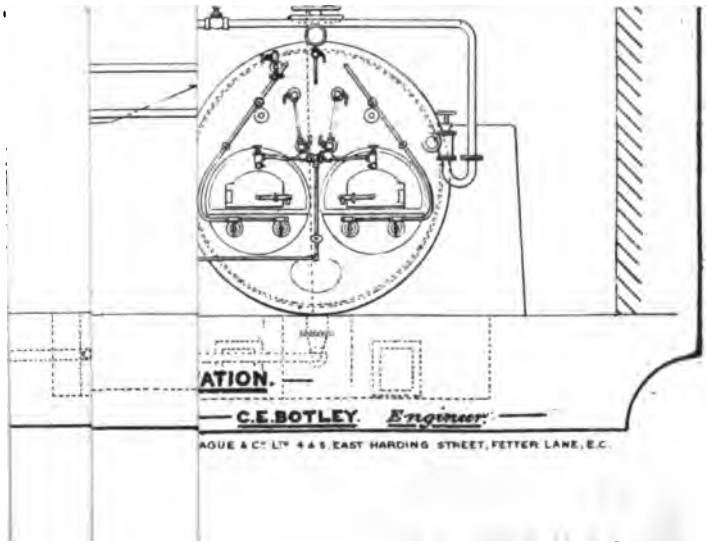
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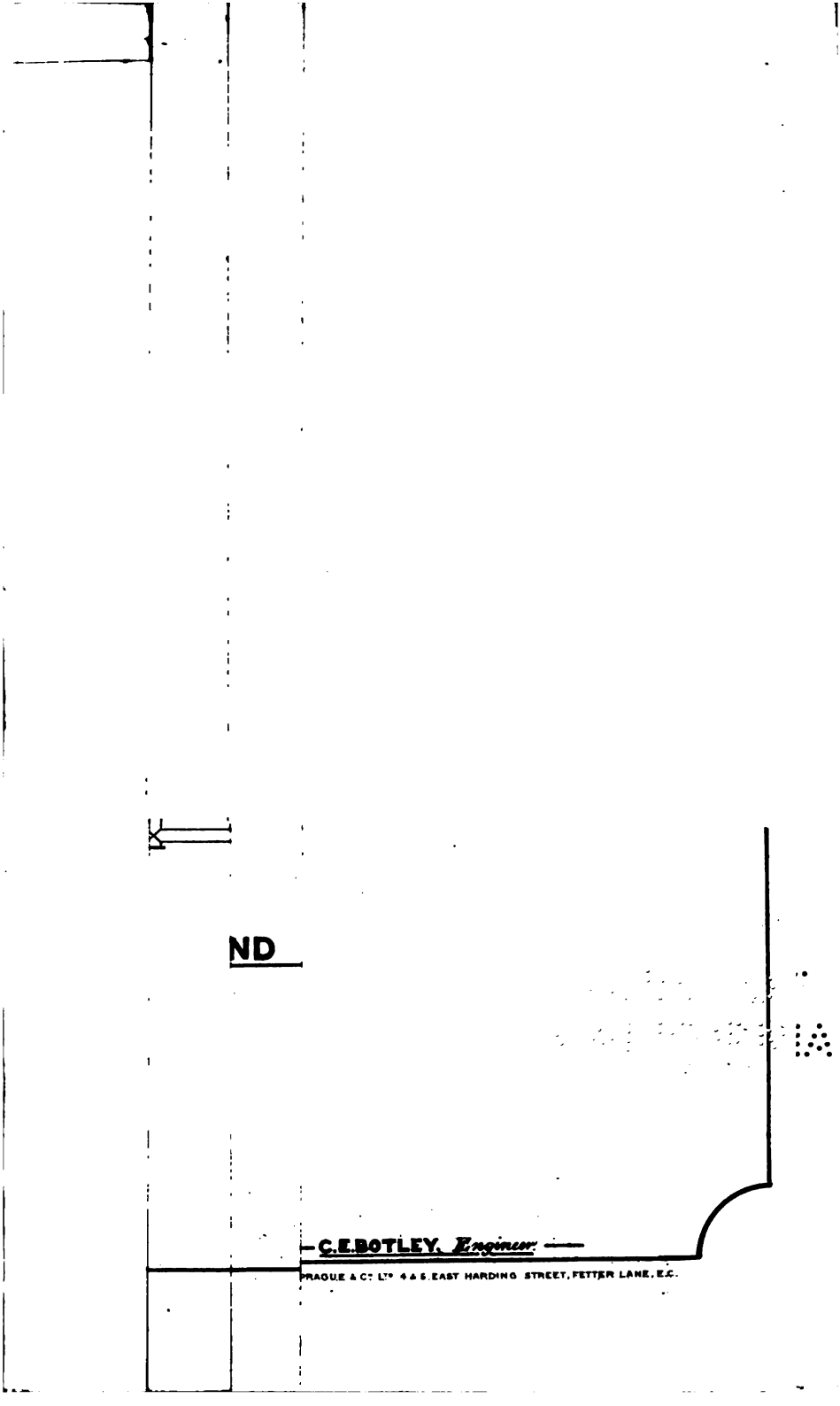
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rather better illuminating value, but has a low flash-point compared with Russian Solar Distillate.

The best results have been obtained from some (discoloured) refined American petroleum, which was very clean in working, made little tar, and a high illuminating power gas. Its use, however, is attended with more risk than the other oils mentioned. There are two modes of expressing the oil value.

1. Candles per gallon =

$$\frac{\text{Illuminating power of gas in candles.}}{\text{Oil used in gallons per 1000 cubic feet.}}$$

$$\text{As } \frac{21 \text{ C.P.}}{3 \text{ gallons per 1000 cubic feet}}$$

$$= 7 \text{ candles per gallon.}$$

This is a simple method, and useful to calculate how much oil is required to give a certain candle-power gas when the value of the oil in candles per gallon is known.

2. Candle-feet per gallon =

$$\frac{\text{Gas made} \times \text{illuminating power.}}{\text{Oil used} \times 5 \text{ cubic feet.}}$$

$$\text{As } \frac{200{,}000 \times 21}{600 \times 5}$$

$$= 1400 \text{ candle-feet per gallon.}$$

This method is preferred, as perhaps more scientific, for it will be seen that the 5 cubic feet per hour rate, as used in the standard tests is taken into account. It may also be noted that candle-feet per gallon is 200 times greater than candles per gallon.

A list of candle-feet per gallon values is given here, and the operator tries to reach 1500 candle-feet in his working per gallon of oil, but this value is not often obtained. The highest weekly record is 1483 candle-feet when making 18·19 candle gas with a very favourable tabular number (under ·950).

As will be seen, the average value, as returned, is more, about 1300 = (6·5 candles per gallon).

TABLE SHOWING THE ILLUMINATING POWER THAT SHOULD BE OBTAINED WITH VARIOUS QUANTITIES OF OIL USED AT DIFFERENT OIL VALUES.

Oil per 1000 cubic feet.	Illuminating Power.				
	Oil Values.				
	1300	1350	1400	1450	1500
2·0	13·00	13·50	14·00	14·50	15·00
2·1	13·65	14·17	14·70	15·22	15·75
2·2	14·30	14·85	15·40	15·95	16·50
2 3	14·95	15·52	16·10	16·67	17·25
2·4	15·60	16·20	16·80	17·40	18·00
2·5	16·25	16·87	17·50	18·12	18·75
2·6	16·90	17·55	18·20	18·85	19·50
2·7	17·55	18·22	18·90	19·57	20·25
2·8	18·20	18·90	19·60	20·30	21·00
2·9	18·85	19·57	20·30	21·02	21·75
3·0	19·50	20·25	21·00	21·75	22·50
3·1	20·15	20·92	21·70	22·47	23·25
3 2	20·80	21·60	22·40	23·20	24·00
3·3	21·45	22·27	23·10	23·92	24·75
3·4	22·10	22·95	23·80	24·65	25·50
3·5	22·75	23·62	24·50	25·37	26·25

Surprise has been expressed that better results are not obtained from the oil with the improved carburetter than those given. It will have been noted that the oil is not wasted in the form of lamp-black or tar, for of the latter from the separator (which also has to receive any liquid from the syphons), when the 50 to 60 per cent. of water is deducted, there is under 10 per cent. of tar and tar oil. Nor is any serious amount of oil deposited in the purifiers, hence the natural question is, if greater illuminating value is in the oil, what becomes of it?

It may be that in the desire to secure a permanent gas the efficiency suffers, or that the conditions of testing are comparatively too severe. It is also only right to state that the figures given for oil used are slightly above the actual, the meters, from circumstances of position and policy, registering somewhat fast.

At the end of the paper some weekly returns of working are given for 1898 and the present year, together with some working directions for the operators of the plant which may be of interest.

Especially since the beginning of this year, great, and almost elaborate care, has been taken to secure accuracy in the returns, which it is ventured to believe show much uniformity of working.

The investigations at Hastings are, of course, far from complete, and one of the most interesting points now under consideration is using compressed gas instead of air as the power for the atomiser.

This account of individual experience will, the Author hopes, suggest many points for discussion to the mutual advantage of all concerned. There will, of course, be some here to-day to whom much of what has been said will be very elementary knowledge, after their many years' experience in the manufacture of water gas, but to those who, like the Author, are comparatively new to the same, it is hoped the paper may prove of interest, and possibly advantage. The following drawings will serve to illustrate some of the points mentioned:—

No. 1. C.W.G. plant, ground floor plan.
„ 2. „ „ stage floor plan and section.
„ 3. „ „ oil stores and tank.
„ 4. General boiler house.
„ 5. C.W.G. plant, purifiers, &c.
„ 6. General purification plant.

In conclusion, the Author desires to acknowledge his indebtedness to his father for a free hand in regard to the preparation of this paper, to his assistants, Mr. F. J. Winter and Mr. H. R. Hyatt, with reference to the tests and drawings respectively, and to his working staff, to whose intelligent co-operation much of the successful application at Hastings of the valuable gas-maker's ally—carburetted water gas—is due.

I.—HASTINGS CARBURETTED

WEEKLY SUMMARY OF

Date.	Gas made as per meter.	Corrected for Temperature.	Hours worked	No. of Set.	(Mixed Gas) Illg. Power for Week.	OIL USED. Kind.	Quantity.	Per 1000 c. ft.
1898.								
August 1	1,156,000	1,108,000	66	2	15·78	Russian	2838	2·56
„ 8	959,000	920,000	55	2	15·82	Russian	2414	2·62
„ 17	1,135,000	1,088,000	64	2	15·95	American ..	2986	2·74
„ 22	853,000	818,000	53	2	15·91	American ..	2219	2·71
„ 29	1,073,000	1,029,000	64	2	15·97	Amer. & Russ.	2775	2·69
Sept. 5	1,076,000	1,032,000	66	2	15·74	Russian	2862	2·77
„ 12	1,081,000	1,086,000	66	2	16·39	Amer. & Russ.	2541	2·45
„ 19	1,115,000	1,069,000	66	2	15·74	Russian	2724	2·54
„ 26	1,146,000	1,099,000	66	2	15·79	Russian	3036	2·76
October 3	1,191,000	1,142,000	75	2, 2	15·73	American ..	3089	2·70
„ 10	1,244,000	1,193,000	70	1	15·75	American ..	3420	2·86
„ 17	1,456,000	1,396,000	76	1	15·51	Russian	3961	2·83
„ 24	1,709,000	1,638,000	93	1	16·10	Russian	4745	2·89
„ 31	1,184,000	1,135,000	66	1	15·63	Russ. & Amer.	3217	2·83
Nov. 7	1,562,000	1,497,000	78	1, 1	16·10	Refined Petro. & Russian	4577	3 05
„ 14	1,317,000	1,263,000	76	2	15·89	Amer. & Russ.	3642	2·88
„ 21	2,050,000	1,965,000	110	2	15·74	Amer. & Russ.	6071	3·08
„ 28	2,706,000	2,594,000	144	2	15·91	Amer. & Russ.	7538	2·90
Dec. 5	2,537,000	2,432,000	140	2	15·80	Amer. & Russ.	7633	3·13
„ 12	2,313,000	2,217,000	132	2	15·54	Amer. & Rus	6738	3·03
„ 19	2,373,000	2,275,000	132	2	15·58	Russian	7059	3·10
„ 26	2,900,000	2,780,000	154	2	15·71	Russian	8632	3·10
„ 31	2,409,000	2,309,000	132	2	15·92	Russian	7719	3·34

WATER GAS PLANT.

WORKING, AUG. TO DEC. 1898.

Average Illg. Power.	Candles per gallon.	Candle feet per gallon.	Cost per 1000 c. ft.			CO_2	REMARKS.
			Labour. (Manf., Repairs and M'nce., Purification.	*Material.* Oil and Fuel.	Total.		
			d.	*d.*	*d.*		
18·11	7·07	1414	1·51	11·51	13·02	4·42	
18 71	7·13	1426	1·55	12·13	13·68	4·21	
18·92	6·89	1378	1·78	12·72	14·50	5·27	CO_2 high in purified gas.
18·83	6·94	1388	1·77	12·37	14·14	5·77	Oxide in one purifier. Some high-class oil used.
16·51	6·12	1224	1·46	12·34	13·80	4·86	Oxide purification.
18·84	6·79	1358	1·66	13·19	14·85	4·33	
18·19	7·41	1483	2·57	11·78	14·35	4·88	No CO_2 in purified gas; high tabular number.
17·86	7·00	1401	1·80	12·05	13·85	4·68	
18·76	6·79	1358	2·21	12·75	14·96	4·52	
18·29	6·76	1352	1·56	12·38	13·94	4·77	
18·21	6·35	1270	1·50	12·77	14·27	4·19	Changing over sets.
17·62	6·20	1241	1·52	12·59	14·11	4·11	
18·94	6·53	1307	1·57	12·60	14·17	4·42	
19·39	6·84	1368	1·61	12·39	14·00	4·50	
19·94	6·52	1304	1·37	13·73	15·10	3·89	
18·04	6·25	1251	1·86	13·37	15·23	3·93	No. 1 set off re generator valves.
19·47	6·30	1260	1·95	14·15	16·10	4·47	
18·07	6·38	1277	1·69	13·40	15·09	4·10	
19·26	6·13	1227	1·45	13·87	15·32	3·95	CO_2 high in purified gas. Change of oil. Heats bad.
19·18	6·31	1262	1·70	13·91	15·61	3·89	
19·19	6·18	1236	1·71	13·85	15·56	3·73	
18·87	6·07	1215	1·52	14·16	15·68	3·60	
20·37	6·09	1218	1·52	14·45	15·97	4·11	

II.—HASTINGS CARBURETTED

Weekly Summary of Working,

Date. Week ending	Gas made as per Meter.	Corrected for Temperature.	Average Gas made per hour.	Average Gas made per run.	C.W.G. Percentage of total Gas made.	Average per cent. CO on Mixed Gases.	No. of Set at Work.	(Mixed Gas) Illuminating Power per week.	Oil used. Kind.	Quantity.	Per 1000 cubic feet.	Per run.
1899.	Thousands.	Thousands.										
Jan. 6	1,714	1,668	17,375	4,389	22·05	..	No. 2	15·99	Russian	5,319	3·18	14·01
„ 13	2,529	2,480	17,464	4,428	22·63	..	„ 2	16·43	Russ. & Amer.	8,255	3·32	14·74
„ 20	2,547	2,476	17,436	4,374	23·91	..	„ 2	15·82	American	8,201	3·31	14·48
„ 27	2,267	2,223	17,927	4,650	21·73	..	„ 1 & 2	15·66	„	7,251	3·26	15·16
Feb. 3	2,515	2,470	19,000	4,678	23·85	..	„ 1	15·65	„	8,153	3·30	15·44
„ 10	2,479	2,425	18,653	4,601	23·65	..	„ 1	16·16	Amer. & Russ.	7,648	3·15	14·51
„ 17	2,350	2,306	19,216	4,530	24·33	..	„ 1	16·04	Russian	7,265	3·15	14·27
„ 24	2,387	2,344	19,533	4,764	28·40	..	„ 1	16·21	„	7,368	3·14	14·97
March 3	2,490	2,453	20,441	4,925	27·55	12·5	„ 1	15·46	Russ. & Amer.	7,549	3·07	15·15
„ 10	2,522	2,480	20,666	4,891	27·63	13·9	„ 1	15·77	American	7,787	3·13	15·35
„ 17	1,345	1,331	19,014	4,703	16·96	..	„ 1	15·70	„	3,971	2·98	14·03
„ 24	2,014	2,008	20,080	4,769	23·76	14·2	„ 1	16·07	„	6,228	3·09	14·78
„ 31	2,259	2,226	20,803	4,849	26·02	14·8	„ 1	15·56	„	6,839	3·07	14·89
April 7	1,110	1,108	19,345	4,714	19·94	14·2	„ 1	15·33	„	3,258	2·94	13·86
„ 14	1,178	1,170	19,500	4,814	15·28	..	„ 1	15·39	„	3,632	3·10	14·94
							Averages	15·82	..	..	3·15	..

WATER-GAS PLANT.

JANUARY TO APRIL, 1899.

Average Illuminating Power.	Candles per gallon.	Candle-feet per gallon.	Fuel used. Total as Coke.		Fuel used. Generator and Boiler per 1000 cubic feet.	Tar Liquor made per cent. of Oil used.	Atomiser Air used per cent. of Gas made.	CO_2 per cent. in crude Gas.	Cost per 1000 cub ft. *Labour.* Manufacture, Repairs and Maintenance, Purification.	Cost per 1000 cub ft. *Material.* Oil and Fuel.	Cost per 1000 cub ft. Total.	Remarks.
			ton.	cwt.	lbs.				d.	d.	d.	
19·04	5·97	1,194	35	11	47·73	20·3	2·76	3·76	1·93	14·42	16·35	5 days only.
20·65	6·20	1,240	51	8	46·42	18·89	2·67	4·28	1·90	14·63	16·53	
20·21	6·10	1,220	54	11	49·34	34·14	2·79	4·10	1·70	14·76	16·46	Separator cleaned.
18·88	5·78	1,157	49	7	49·72	19·3	2·42	3·22	1·50	14·61	16·11	Changing sets.
18·35	5·55	1,111	51	10	44·96	19·13	2·42	3·09	1·59	14·53	16·12	New chequer work in carburetter.
19·14	6·06	1,213	52	13	48·63	20·92	2·44	3·15	1·59	14·22	15·81	
18·94	6·01	1,202	46	15	45·40	26·42	2·35	3·11	1·64	..	..	5473 galls. oil used from surplus.
18·90	6·01	1,202	51	4	48·92	26·05	1·91	2·75	1·58	..	..	3126 " " Blow off air measured from this date.
18·35	5·96	1,192	53	3	48·52	18·01	1·76	2·37	1·76	14·20	15·96	
19·93	6·34	1,269	51	12	46·60	15·42	1·89	2·53	1·41	14·77	16·18	
19·42	6·50	1,301	30	2	50·64	30·21	2·07	2·69	1·75	14·44	16·19	
19·96	6·44	1,288	43	8	48·40	14·78	2·02	2·74	1·33	14·73	16·06	
19·72	6·41	1,283	45	12	45·88	16·96	1·92	2·80	1·59	14·47	16·06	
20·29	6·90	1,380	23	11	47·60	19·64	1·80	2·55	1·89	14·08	15·97	Tests exceptional. New condenser on. Tar liquor has contained 50 to 60 per cent. of water.
19·98	6·43	1,287	24	3	46·23	17·62	2·00	2·28	1·58	14·61	16·19	
19·45	6·24	..	..		47·66	21·15	..	..	1·65	14·50	16·15	

III.—HASTINGS AND ST. LEONARDS GAS COMPANY.

Carburetted Water Gas Plant.—Working Directions.

From blowing to start an ordinary Up Run (to make Gas):

1. Reduce engine speed.
2. Lower blast valve on carburetter.
3. Lower generator blast valve.
4. Turn on steam.
5. Close stack valve.
6. Put on oil. (Air first, then oil.)

Note.—If blast is on superheater, this must be shut off before 2.

To stop an ordinary Up Run:

1. Turn off oil (oil first, air after).
2. Put engine up to full speed, carefully.
3. Turn off steam.
4. Open blast valve on generator, gradually to full extent ("to blow over").
5. Lift stack valve.
   (Adjust generator blast, if required).
6. Put blast on carburetter, as soon as it will light.

To start a Down Run:

1. Put engine to slow speed.
2. Lower blast valve on carburetter.
3. Lower blast valve on generator.
4. Lower reversing gas valve right down
5. Turn on steam.
6. Close stack valve.
7. Put on oil.

Note.—If blast is on superheater this must be shut off before 2.

To take off Down Run:

1. Shut off oil.
2. Raise reversing valve smartly.
3. Put engine up full speed.
4. Shut off steam.
5. Put blast on generator to full, open carefully.
6. Open stack valve, and adjust generator blast, if required.
7. Put blast on carburetter, as soon as it will light.

To clinker after blowing over (see that oil is shut off at meter).

1. Reduce engine speed.
2. Open generator cautiously.
3. Put on coke, 3 or 6 cwt. according to circumstances. (It is always best to leave a bright fire to clinker.)

4. Open ash pan door.
5. Open clinkering doors, two at a time, clinker thoroughly and close doors.
6. Close ash pit door.
7. See blast pressure is all right, or make sure by increasing engine speed. Then close up generator.
8. Open blast on generator by degrees.
9. When fire is through generator put blast on carburetter.

To coke up (after blowing over).

1. Drop generator blast valve.
2. Open generator cautiously.
3. Put in coke. It is better to put on 3 cwt. at a time, whenever possible.
4. Open generator valve by degrees, up to full extent.
5. Put blast on carburetter, as soon as it will light.

Operator to prepare for and shut down plant for an ordinary stop.

1. Fill oil reservoir up for say 2 runs above working level.
2. Then close regular cocks on oil supply pipe to reservoir. (Watch pressure of section does not rise.)
3. After last run and blowing over, close air and oil cocks on atomiser supplies.
4. Close gauge cocks on oil reservoir.
5. Shut off water from scrubber and washer.
6. Close outlet valve of scrubber.
7. Stop engine and open relief valves on blast pipe.

Operator to prepare and restart plant to make gas after ordinary stop.

1. See engine and fan started and then close relief valves on blast.
2. See that circulating water pump, oil pump and compressor are started.
3. Open blast valve on generator and blow over carefully.
4. Clinker, if necessary.
5. Put water on scrubber.
6. Put water on washer and regulate same. See that it runs clear through seal cup at bottom.
7. Open outlet valve of scrubber.
8. Open cocks on oil supply pipes and gauge-glass cocks on reservoir.
9. Open air and oil supplies to atomiser.

IVA.—HASTINGS GAS-WORKS LABORATORY.

TESTS ON PURIFIED CARBURETTED WATER GAS FOR CARBON MONOXIDE (CO).

Date.	Absorption by Bromine, Nitric Acid and Alkaline Pyrogallol.	CO %.	CO_2 % (Unpurified Gas).	Illuminating Power.	Make per Run.	Coke used in Generator per 1000 cubic feet.	Remarks.
1899.				candles.	cub. ft.	lbs.	
Feb. 25th	12·6*	30·2	2·3	18·29	4964	44·58	* Nitric
„ 27th	10·8*	32·9	2·3	17·81	4880	44·37	acid not
Mar. 1st	10·4*	31·2	2·2	17·97	4847	42·40	used in
„ 3rd	6·6*	33·9	1·9	20·27	5011	41·31	making
„ 9th	12·5	32·0	2·6	19·41	4790	42·40	these
„ 10th	13·3	31·0	2·6	18·44	4752	43·24	tests.
„ 11th	14·2	30·9	2·4	18·65	4604	40·72	
„ 27th	10·4	32·3	2·8	17·59	4906	39·81	
„ 28th	11·3	32·7	3·1	18·37	4800	46·66	
April 5th	11·5	34·3	2·2	20·06	4619	41·56	
„ 10th	13·3	30·5	2·6	20·65	4578	50·20	
„ 10th	12·6	32·0	2·2	20·48	4578	50·20	
„ 11th	12·6	33·0	2·1	19·60	4731	43·29	
„ 11th	12·9	32·3	..	19·76	4731	43·29	
„ 11th	12·4	33·4	2·3	18·68	4731	43·29	
„ 12th	12·8	33·1	2·1	20·33	5024	39·14	
„ 12th	14·4	31·8	..	20·65	5024	39·14	
„ 12th	12·9	32·6	2·0	19·41	5024	39·14	
„ 13th	12·6	33·2	2·0	..†	5025	33·43	† Tests
„ 13th	12·0	33·8	2·2	..†	5025	33·43	unreliable
„ 14th	13·0	32·4	2·5	21·20	5219	36·11	

IVB.—HASTINGS GAS-WORKS LABORATORY.

Tests on Enriched (Mixed) Gas for Carbon Monoxide.

Date.	Absorption by Bromine, Nitric Acid and Alkaline Pyrogallol.	CO %.	Percentage of Carburetted Water Gas on Total Gas Made.	Remarks.
1899.				
Feb. 28th	5·8*	11·9	30·76	* Nitric acid
Mar. 1st	5·5*	12·6	30·83	not used
„ 2nd	6·4*	12·7	31·31	in making
„ 3rd	5·9*	12·9	31·73	these tests.
„ 4th	3·3*	12·7	31·72	
„ 9th	7·5	15·1	30·58	
„ 10th	8·4	13·9	30·46	
„ 20th	13·6	14·4	17·45	
„ 21st	6·2	14·2	20·05	
„ 22nd	7·5	14·3	34·88	
„ 23rd	6·6	14·1	36·27	
„ 25th	6·4	14·8	35·87	
„ 27th	6·6	14·7	18·46	
„ 28th	7·3	14·3	13·62	
„ 30th	7·3	15·5	18·68	
April 6th	7·1	14·4	17·44	
„ 7th	7·6	14·1	17·44	
„ 10th	7·1	11·5	16·02	
„ 11th	7·2	13·9	17·03	
„ 12th	7·3	14·0	18·11	
„ 13th	7·6	14·9	17·44	
„ 14th	7·9	13·6	18·40	

DISCUSSION.

Mr. J. W. Helps: As no one seems particularly anxious to get up to commence the discussion on this paper, perhaps you will permit me to make a few remarks. I am sure you, sir, are perfectly right in saying that the managers of gas companies about to start the manufacture of water gas will find in Mr. Botley's paper a great deal that will be of assistance to them, if they are not frightened at the mass of detail contained in the paper, which foreshadows certain difficulties they will have to meet with. The paper will also enable them to avoid certain difficulties which Mr. Botley has met with and has happily overcome; and therefore, perhaps, they will have a much happier time than he has experienced. It will also be of considerable value to those students who are looking up the question of water gas. Whatever may be said as to the paper, no objection can be taken to it from the point of view of completeness, for Mr. Botley has entered into the general routine of the subject, has given the details of those plants which have been adopted up to the present time, and dealt with matters most thoroughly. But from the point of view of those managers who, like myself, have been using water gas for a considerable time, I must confess to a feeling of disappointment. I did expect from Mr. Botley, knowing how keen he is on originality, and how keen he is on improving matters, never being satisfied with the results he is obtaining, but always looking forward and expecting to do better every day, I did expect he would have given us certain figures and certain facts which would have been more of use to those who have been carrying out the process of manufacturing water gas for some time past. It appears to me there is only one point in the paper which is new, that is the question of the manner in which the oil should be introduced into the carburetter. I have had the pleasure of seeing the plant at work and Mr. Botley has shown me the manner in which the oil spray is introduced into the carburetter. I must honestly confess that I came to the conclusion that he was doing the right thing in the right way. Mr. Botley showed me, by turning out one of the oil sprays, the condition in which the oil mist went into the carburetter, and if he could maintain the condition of the oily mist when it was inside the carburetter

as well as he could when it was outside I cannot help thinking that the manner in which he was doing that work was bound to be successful. But the whole thing appears to me to resolve itself into a question of £ *s. d.* Mr. Botley has compared his process with that where the oil is introduced into the top of the carburetter, but in doing so I think he has made one little mistake. He says the oil is introduced through a sprayer and falls directly upon the hot brick chequer work and from the chequer work through the carburetter. If that were so I could fancy that the difficulties which Mr. Botley foreshadows would arise. In our case with the plant we have in use the oil does not fall directly on to the brickwork but on to the intervening iron bars, and therefore the oil is volatilised in a somewhat different manner to that which Mr. Botley thinks, and it is not choked up in the manner in which he imagines with carbon. Now I have been looking through the figures given in the appendix of Mr. Botley's paper, and I naturally expected from the manner in which he was introduciug the oil that his results in candles per gallon would have worked out very much better than the figures we have been hearing of and the figures we have been experiencing for some time past. I think, practically speaking, he has obtained something under 6½ candles per gallon per 1000 cubic feet. I do not know whether that is a better result than he was obtaining previously when he was injecting the oil at the top of the carburetter in the form of a spray. If Mr. Botley can give us that figure so as to enable us to make the comparison it would help us as to the advantage obtained. It would not be fair to say, simply because Mr. Botley is not getting as good results as I am at the present time, that that is due entirely to the system which he adopts with regard to the admission of the oil, because I have been getting better results than some people who are injecting the oil in the same way as I do. I think that is a point that wants looking into, because if Mr. Botley's system is the correct one it should result in a saving of oil, and inasmuch as the cost of oil means nearly three-fourths of the whole cost of making water gas the question is a serious one. Mr. Botley says he is able to regulate the amount of oil admitted to the carburetter according to the amount of gas which is coming off at each minute of the run. From what I saw at Hastings I think Mr. Botley is doing that most thoroughly, and that I think is the best thing to do. Mr.

Botley also says he is able to do away with that blowing off of the oil which remains in the carburetter at the end of the run, which he considers a disadvantage, and he says he is also able to greatly reduce the quantity of water gas tar at the inlet of the relief holder, which is found to be a very great nuisance in the manufacture of water gas. From that he deduces that he is practically volatilising and making into permanent gas the whole of the oil which goes into the carburetter. He, however, makes the statement in another part of his paper, that it is necessary to clean out the down-pipe of the superheater to the washer every three weeks or so, because he finds it gets choked up with carbon. Now it appears to me that here is where the solution of the whole question lies. Mr. Botley does not get oil in the holder because he burns it into carbon somewhere. I do not find it necessary to clean out that down-pipe oftener than once in three months. I do not think it would be of any interest to those present to go into details and give figures, but I may say I have obtained results very nearly a candle higher than those obtained by Mr. Botley. I think if Mr. Botley wants to show that his system is the correct one he should be able to show that he is getting equally good results with those obtained at Croydon, because I am using oil of exactly the same character and the coal is very much the same. But both the results from the pure water gas and the admixture of coal and water gas are better at Croydon than they are at Hastings. There are many points one would like to draw attention to, but that is the point which is of interest to those who are making water gas and upon which we require a little more information before we can decide whether Mr. Botley is right or wrong.

Mr. F. W. Cross (Lea Bridge): The same point has occurred to Mr. Helps as has occurred to myself as to the deposit in the down-pipe to the washer. Mr. Botley, I gather from his paper, works at low heats. If he works the superheater at low heats he should not get any deposit in the pipe leading from the superheater to the washer that would require removing; at any rate not within three weeks or a month, probably more than that. It appears to me that working at these low heats with his automiser, he has deposited some of his oil in the down-pipe that should be in his gas. There is one other point that has been brought prominently forward in the paper, that may have some bearing on the low candle efficiency that

Mr. Botley has obtained—that is the oil he gets into his purifiers. I have worked a similar apparatus for more than two years, and I have never seen the slightest trace of oil in my purifiers when I passed the whole of the coal and carburetted water gas through them, nor afterwards when I passed the carburetted water gas through the separate purifiers. It appears to me that Mr. Botley is losing some of his oil in that way. If I am free from oil in the purifiers I take it I get it in my gas; if Mr. Botley gets oil in his purifiers he is not putting it in the right place. There is one other point as to the mixture of tar and water. Mr. Botley says he is sending out his tar with from 50 to 60 per cent. of water. I cannot quite understand such a high percentage as that. Of course it is true the tar must have some percentage of water in it, and a high percentage; but I should have thought the percentage should not be more than 20 or 30 per cent. at the outside. Further, the amount of water in the tar may be easily reduced by evaporation or steaming. If you put through your ordinary tar tank a steam coil—of a primitive kind for experiment will do—you will find you can drive your water down to 10 per cent.

Mr. A. E. Broadberry (Tottenham): I wish to express my thanks to Mr. Botley for the very useful paper he has laid before us. He has entered very deeply into details, and among the thousand and one points he has put into his paper, it is very certain there are a few we are bound to disagree with. With regard to purifiers Mr. Botley says they should be in the open. Of course it is generally considered that purifiers are better roofed in, and for my part I do not see any more reason for putting water gas purifiers in the open than coal gas purifiers. When we are going to empty one of the water gas purifiers we air it first of all by blowing air through it for about two hours beforehand. That is not done from the fans as Mr. Botley suggests, and I do not think it would be a good plan to connect it with the blast fans. We have a separate blower which we use for the purpose, and we do not find any very great risk. I cannot see the need for putting the purifiers in the open. In regard to purification, Mr. Botley says it is difficult to remove the sulphuretted hydrogen. We test our gas for sulphuretted hydrogen with a constant test bottle, carrying lead papers for a week, and we are able to keep our

lead papers clean for a week. The oxide certainly does get a little bit oily, but the oxide we have in use now has been in use for the last four and a half years, so it is not a very serious matter. I think most of the little troubles Mr. Botley has put in are chiefly individual troubles; and I do not think need prevent any one from putting in a carburetted water gas plant. Mr. Botley speaks two or three times about explosions and pops and so on, and some of you might be led to think he has suffered a great deal from them, but by Mr. Botley's courtesy I visited his works not very long ago, and while I was there I certainly did not hear a pop even, and certainly so far as our own plant is concerned the pops do not amount to so much as is often heard from the banging off of a coal gas retort. In regard to purification there is a point as to which I do not quite agree with Mr. Botley. He says it is cheaper to remove the carbonic acid than it is to enrich against it. It may be more desirable to remove the carbonic acid than to enrich against it, but I do not think it is cheaper to do so. Supposing you add 4 per cent. of carbonic acid to the bulk of the gas. Mr. Botley takes it there would be a reduction of from 3 to 4 candles; I have never found it so. I should imagine it would be from 1½ to 2 candles. I do not know whether Mr. Botley has allowed for the bulk of CO_2, but that would go to the consumers' meters and be sold to them, and it represents nearly ½*d.* per thousand cubic feet. I admit it is perhaps not the most scientific course, but so far as lighting is concerned, it does not matter very much to the consumer whether his 16-candle mixture contains carbonic acid or any other mixture. Another point I can hardly understand is that Mr. Botley says that the amount of water used is about six gallons per thousand cubic feet of gas made. Does he mean that is the water used for the generator only, because I find it amounts to about ten gallons for evaporation, taking the engines in as well. But taking Mr. Botley's six gallons per thousand, supposing he was making 40,000 cubic feet of gas per day, he would only be using about 240 gallons a day. I think that is a long way off the mark. In the paper I notice he said something about naphthalene troubles at Tottenham, having been attributed to the carburetted water gas plant, and would like some further information on the point. I think it must be evident to everyone that the temperature at which the oil is cracked must

affect the composition of the gas, and that it is quite possible to alter the composition of the gas by having too high a heat. At my own works I have noticed that when we got our checker work too hot, we did produce naphthalene from carburetted water gas. In one of the wells where the syphon is self-emptying, we did find a good many flakes of naphthalene hanging all round it. At the same time it is a very insignificant amount compared with that made from coal gas. However after these points of disagreement, I come to the new sprayer. Mr. Botley very kindly did for me what he did for Mr. Helps. He took the sprayer from the carburetter and directed it across the floor. Mr. Botley explained that the sprayer could not be expected to work as satisfactorily in a horizontal as in a vertical position, which you can very easily appreciate. But working at this disadvantage it blew out the oil in such a fine mist that it floated away like steam out of the ventilators in the roof. If we could put our oil into the carburetter in that condition it seems to me it is a much more favourable condition for the purpose of gasifying the oil than putting it in in the form of a heavy shower, even if it were put in direct on the top of the checker work without providing additional space. But it certainly does not seem from Mr. Botley's figures that there has been that very great increase of illuminating power from the oil results that I should have expected from the device. Mr. Botley says he has less lamp-black now than he had before in the take-off pipe. I also notice that he gets less tar, which he puts down at 10 per cent. of the oil used, and, roughly speaking, 10 per cent. of the oil used would be one-third of a gallon for each thousand cubic feet of gas made. I find ours works out at half a gallon, the difference in lamp-black and tar should show in oil results. Mr. Botley says he finds the best results from the sprayers having the smallest holes; and if he wants to put in more oil, and he uses sprayers with larger holes, he does not obtain such good results: I would suggest that instead of larger holes he should put in more small holes. In one place he mentions he cleared out some checker work from the carburetter, but he did not find any advantage from that. That leads me to wonder whether it is necessary to have that cone which he places at the top of the carburetter. If Mr. Botley does not find any advantage from taking out some of the checker work, is there any need to raise the carburetter; is

it necessary to move in the direction of giving more space above the checker work. If it is not necessary, that fact would considerably simplify the adapting of his sprayer to ordinary plants. I think that undoubtedly Mr. Botley's sprayer is a good idea, and I think in the future he will be able to lay some better figures before us than he has been able to do in his paper.

Mr. T. MAY (Richmond): I should like to say a word or two, though I have had no experience of carburetted water gas. The information we have just had given to us seems to point to the fact that the system of spraying is not in fault, but that it is the plant that is wrong, and that if the sprayer could be applied to the other systems that have been referred to, better results might be obtained by its use.

Mr. C. F. BOTLEY (Hastings): The plant was constructed to the designs of my father. It was erected by Messrs. Plant, Shalford and Company.

Mr. S. MEUNIER: I must congratulate Mr. Botley very much indeed upon this very practical paper. I particularly admire the truthfulness with which he has put down the various costs. I should judge from my own experience, after taking into consideration the various local circumstances which arise in different towns, that they are sufficiently close for anyone who is thinking of putting down a carburetted gas plant to judge by. But the main feature which strikes one is that his oil results are not equal to what some of us are getting. Certainly 6½ candles per gallon per thousand does not appear to be what we might expect, not only from what we have heard as to the spraying, but also judging from what I saw the last time I was at Hastings. I must certainly confess to a strong feeling of disappointment in the results obtained, judging by that standard, perhaps, I expected a great deal; I am only sorry that Mr. Botley has not given us some figures which are the best on record. Evidently the fault lies not so much with the sprayer, which appears to be the correct thing, as with the heat he uses in his plant, or something, perhaps, he has not yet discovered. Mr. Botley makes the remark that we want to choose sober intelligent men. That, of course, with a plant of this sort, is an absolute necessity; and I only wish we were in a position to get that kind of men. Whether they are to be got in the south I do not know, but there is very extreme difficulty

in getting them in the north. I have put down the very varying results I have at times obtained to the fact that when there is nobody in authority around, the men are not sufficiently careful to look after the heats. After all, human nature is human nature, and when one's back is turned every man's sense of duty is not sufficiently great to assure that journey down the stairs and up again after every run to see whether the heats in the superheater or carburetter are right or wrong. To the method of judging the temperature in a rough and ready fashion may be due the fact that results do vary considerably. I have had anything from 5 candles per gallon per thousand up to 8 candles. Unfortunately one cannot keep up to 8 candles regularly, taking it over a long period, but we have no difficulty in striking somewhere in the neighbourhood of 7½ candles, which is a fairly good result. I am certainly of opinion there is more in the working of a carburetted water gas plant, than we have yet discovered. Its adaptability and ease of working lend a charm to the whole thing, but there are improvements which require to be made to further facilitate its use and to do away with that human element which you find in a rough and crude form in the working man. In a plant of 500,000, and using 15 gallons of oil per run of seven minutes, I have obtained without difficulty a gas of 23 to 24 candles on the average. As to the question of naphthalene which Mr. Broadberry has mentioned I certainly consider that his explanation is the correct one. I have for a long time had an idea that carburetted water gas tar was worth a great deal more than ordinary coal gas tar, but so far cannot come to a definite conclusion, and the analyses we are continually making show some very peculiar things. At times we find a good deal of naphthalene in the tar itself, due no doubt to the personal element; another time we find a great deal of vitrifiable benzol and no naphthalene; there is no doubt that we want to evolve some improvements or method by which all these difficulties of the human element will be overcome and regular and reliable results obtained whether it is 7 or 7½ or anything else. Another figure which Mr. Botley has mentioned is the cost of renewing the lower portion of the lining which he has put down every three or four weeks. That is a very short time indeed. Whether it is due to the quality of the blocks or what, of course he knows best; but judging from the cost I should certainly say he must be paying for

something very good, whether he gets it or not. We renew ours every two months; but instead of paying 10*l.*, our cost only works out at 4*l.* 10*s.* There is a great difference between 4*l.* 10*s.* every two months and 10*l.* every three or four weeks, and it is certainly an item to be taken into consideration. The fact that Mr. Botley only obtains 6½ candles per 1000 cubic feet is no doubt due to what has been pointed out, that his heats are low, and that is further borne out by the fact that he mentions in his paper, that there are such little things as "pops" and "blows," and such like. If he will keep his heats sufficiently high to ignite his gases as they come over he will get nothing of that kind, and I venture to say that in all probability he will get better oil results. There is another point that is mentioned here, the danger, I take it, of a low flash oil. On page 161 he says the best results have been obtained from some refined American petroleum, which was very clean in working, made little tar, and a high illuminating power gas. Its use, however, is attended with more risk than the other oils mentioned. I should like Mr. Botley to explain in what way he found, or suggests, that there are more risks in working with this oil than the ordinary oil most of us have; because when you take your oil from your tank and pass it through the pump under pressure, it is if gasified free from any liability of contact with the air so as to form an explosive mixture, and I should like him to explain his particular point if he will. I am very much obliged to Mr. Botley for the paper. As I said before, it is very full of detail, and it will certainly be very handy for reference in the future.

The PRESIDENT: Before closing the discussion I may be permitted to make a few remarks. I have not a water gas plant myself and am therefore unable to follow very much of the useful information contained in this paper. We were about to put one down this year but cancelled the contract, awaiting the development of the benzol system, because I am pinning my faith upon uncarburetted water gas, which I hope will in a very short time become a *fait accompli.* Referring to the paper itself, I should like to mention the sprayer. Mr. Botley lays great stress on that, and I think to a great extent he has every reason to do so. Some twenty or twenty-three years ago I was called upon by an American firm to report upon an apparatus for making oil gas by what is now called the Pintsch

process. I experimented upon that for some time, and got fairly good results, but it occurred to me then that, instead of dropping the oil upon a heated pipe, I should secure much better results by spraying the oil into the heated tubes. I did so, and took out a patent for that, and the results I obtained were such that I was able to dispose of it to considerable advantage, and it has been used in many processes since. I found exceedingly superior results from spraying the oil into the tubes than by allowing it to drop or to trickle in. At Vauxhall I tried the spraying of oil by steam into the retorts, and up to a certain extent had good results, but, being handicapped by pressure of other work, I had to let the matter drop. It seems to me the spraying has a distinct advantage over any process by which you drop or trickle the oil on to the checker work. Mr. Botley has referred in his paper to the separation of tar and water by a centrifugal machine. The centrifugal machine I would adopt is a Danish invention patented by Krazenbuhl in Copenhagen. It was my privilege to employ the first machine that was made. It was originally intended for separating milk and cream, and I believe I am correct in saying it has been sold by the manufacturers, the Danish firm of Burmeister and Wair, in thousands in all parts of the world. We made our own experiments with it for separating the tar and liquor, and we really brought the thing to a very great success. But financially it did not suit me to continue, because separating the tar and liquor was a very expensive process and I could get excellent prices for the tar without. My friend, Mr. Irminger, has steadily worked that centrifugal process ever since, because he is not in the same happy position of being able to command the same prices for his tar. If Mr. Botley will try the centrifugal machine he will be able to separate the tar and water to the utmost satisfaction. Touching the tar itself coming forward, it seems a very great nuisance to find it in the water gas apparatus, but if some gentleman will try a modification of this apparatus I have no doubt he will be able to overcome the difficulty. I have been in communication with some firms in England with the idea of inducing them to try it. I am particularly interested and shall be very anxious to hear that some one will put up a small apparatus and see if it will effect the purpose. Then another matter of importance is the dust arrester. Every one who works a water gas plant

has a good deal of trouble with the dust from the smoke stack. Two years ago I designed a Portland cement works, which are now working very successfully in Denmark, and we were at first very much troubled with this dust nuisance. I had about three actions at law pending, threatening me on this matter. But we have overcome that difficulty, and perhaps I may show you how easily it can be done. We are allowing our wet slurry, a mixture of clay and lime, to trickle down on to a cylinder, and by a fan placed at the end we suck up hot air through this flowing mass. The result is that we get a perfectly dry slurry, but in the passage of the air through the tube we take away a large amount of slurry dust which is accumulated in the chamber above. At the same time a great deal escapes with the steam, through the openings at the top of the chamber, and by escaping, covers the trees and gardens of the neighbourhood, causing a great deal of trouble. We have put up a little box or house over the escape, and by means of a spray fed with water pumped from below we wash down all the dust to the bottom of the chamber and then remove it by a worm to a place where it can be remixed with the slurry. So when you are troubled with too much dust in connection with a water gas apparatus you might with advantage try a spray of water put over the smoke stack. I should be only too pleased to furnish you with the drawings of such an apparatus if you will only write to me. There is another matter I wish to mention, that is the ultimate cost of water gas into the holder, I have never been able to pin the water-gas men down to what it costs for labour, repairs and purification of the gas into the holder. The figure is roughly given as from 1*s.* to 1*s.* 9*d.* per thousand cubic feet. Taking the normal cost of oil at 5*d.* per gallon I would like to know the cost into the holder?

Mr. Botley: As far as we are concerned it is 1*s.* 4*d.*

The President: Otherwise I think it is a most interesting paper, and all those who, like myself, are coquetting with this system, will take it home and study it with a great deal of pleasure. I am sure we are very much indebted to Mr. Botley for placing all his experience at our disposal.

Mr. T. S. Lacey: I may mention in reference to the method of removing the dust from cement works, that an almost identical system is now in use for dealing with the dust in the stacks of water gas apparatus.

Mr. CHAPMAN (Harrow): I have an almost exactly similar apparatus, but it has not been at work yet. I believe a similar apparatus is also at work at Plymouth.

Mr. T. S. LACEY: I believe the apparatus for removing the dust in this way is extremely effective. I would like to ask Mr. Botley how much air he uses with his spray, because it is obviously hardly a suitable agent in this case, if it is used in any large quantity. If it were used to the extent of 1 or 2 per cent., I think it is quite possible it would affect the results seriously, because it would add nitrogen, and the oxygen used would tend to burn up the oil immediately into carbonic acid, and thus waste the oil. It is necessary to be very careful in using these figures of candles per gallon and so forth at present, as there is no standard method of testing these oil gases of 20-candle power. The method used by Mr. Botley of testing his 20-candle gas may not be the same as at other places where 20-candle gas is made. I do not think it is at all wise to take these candle values as if they were £ *s. d.* or things that we could weigh. As a matter of fact no one can determine these figures to 1 or 2 per cent. Water gas is different from coal gas, our experience of burning it in the most effective way is limited, and I suppose every one tests it in the way he thinks best. Although Mr. Botley's figures may not show up so well as some obtained by others, it may be found that in the mixed gas, he gets as good results as those whose figures taken on the oil gas alone, may be more favourable.

The PRESIDENT: I should like to ask Mr. Botley what is the limit of water gas that may be used without affecting the burners at present in use. Would he be able to put in 25 or 30 per cent. without upsetting all the arrangements?

Mr. C. F. BOTLEY: I seems to me I have got rather a tall order, and I am afraid I shall not be able to answer everything. There are one or two points occur to me where probably the paper has been misleading. As to the testing I think there is a great deal in that. Personally speaking I have not a satisfactory standard. We have used three standards. We have also lately had occasion to make a number of tests with candles of two makes; and we find the difference between those two makes of candles varies from 1 candle to 1¼ candles. That has been established as the result of making 104 tests. It is herefore only fair to assume that other gentlemen who have

criticised these figures—in a way with which I am very pleased because the paper was written with the object of eliciting criticism—have taken tests which are not on all fours with our own. With reference to the results and what improvements have been made, I am sorry Mr. Browne, who used to be at Hastings, did not bear me out on the subject. He would have told you the results we are obtaining now are vastly superior to what we did obtain previously. A statement was prepared to April, 1897, though the returns were not taken as carefully then as they are now, but up to that time we got 5½ candles; now we get 6½ candles per gallon. That is all the evidence I have to go upon, I do not know anybody else's experience. I can only judge of my own results. I try to improve these results, but if they do not come up to other people's, I shall have to go further afield because I mean to get equally good results to theirs. But until such time as we get a standard method of testing, it is very difficult to compare the results of different plants. I have given in the paper a list of those things which will affect the questions. The first we come to is the size of the plant. Most gentlemen who have spoken are working with a larger plant than I am. That handicaps me considerably. One gentleman says we are making more per run than he does; it may be that the velocity through the jet may account for that, and that the time contact with the chequer work is vastly less than with a bigger set. Then we use it simply and solely for enrichment; and we correct for temperature. I would suggest to those gentlemen who have any idea of comparing this at any future time with any other plant to bring the others to the same standard whereby they may make a fair comparison. I think they may be misleading themselves unless they look very carefully into that matter. So far as I am concerned, the results we are obtaining now are so much better than we did, that I am not so disappointed. My father has come back from other works and told me they have done so and so down there. I do not know the details of everybody else's work. This represents very accurately our results at Hastings; and unfortunately we do not seem to be doing so well at present as at other places. Now there is another matter—the down-take pipe. Surely some of the gentlemen who have criticised me have misunderstood me entirely. We open this pipe and clean it, and take out about a bushel of carbon which collects round the pipe about three-quarters of an

inch thick every two or three weeks. It does not strike me it is lamp-black. In the pipe we have an oil-heater coil, and this occupies a large portion of the pipe. We open this pipe to take the scale off, but I positively deny that it is lamp-black at all. One gentleman tells me I am working at too low heats, and another gentleman says I am working at too high heats. But perhaps Mr. Helps will permit me to say that when he was at Hastings the heats we were working at were as nearly as possible the same as his own.

Mr. HELPS: That is so in regard to the heats, but you say that the pipe requires cleaning every two or three weeks.

Mr. BOTLEY: Perhaps that is rather strong; we have just to take the scale off the pipe every two or three weeks. I am going to take the oil-heating coil out, as I find it is no advantage with our sprayer. As to eliminating the sulphuretted hydrogen, Mr. Broadberry is quite a champion for carburetted water gas, but the price of oil at Hastings and Tottenham is a very different matter, and we find it better to eliminate the CO_2 as far as we can. I find it difficult to add as much oil to the gas as will overcome the effect of carbonic acid. For our present purposes it is a very great inconvenience to have to work the oxide; therefore it pays us much better to work with lime. We are, however, going to work with oxide. As regards the separation, I cannot say that it is satisfactory in every sense of the word, but we are constantly making experiments as to that. Several very valuable suggestions have been given to me by Mr. Hunt, and another member present, one is to put in a steam coil, and evaporate some of the water. I hope eventually to convert all the tar we are making into carbon and gas. The limit of the mixture of water gas with coal gas that our President has asked about, is a matter of wide diversity of opinion. Personally, I prefer to supply coal gas for cooking and domestic purposes. Other gentlemen have used the mixed gas in large proportion without any difficulty. We mix up to one-third of carburetted water gas, making the illuminating power as nearly as possible sixteen candles. Our average is 15·82. I certainly do not care for carburetted water gas for industrial purposes. That is my impression at the present time, but I shall take means to verify it, and if I am wrong I shall correct it.

The PRESIDENT: How much could you put in without upsetting everything; without having to adjust your burners?

Mr. BOTLEY: We put a third. I believe Mr. Broadberry puts in 50 per cent.

Mr. BROADBERRY: We have to adjust the governer burners. The ordinary 5-feet governor will pass a little over 4 feet.

Mr. H. E. JONES (Stepney): Fifty per cent. can be used with an ordinary burner and you can see it in use at the present time. I should like to ask why the Author has formed this idea about using coal gas for industrial purposes. Will he give us a few points from his experience, because I cannot say that I can follow him.

The PRESIDENT: I should like you to give us the cost?

Mr. BOTLEY: In my paper I have included the cost of labour for repairs and maintenance, manufacture and purification—labour only. The average cost for this year is 1·65*d.* per thousand cubic feet. Material, including oil and fuel for generator and boilers, but without lime for purification, 14·50, making a total of 16·15*d.* per thousand cubic feet.

The PRESIDENT: Without lime?

Mr. BOTLEY: Yes, without lime.

The PRESIDENT: That is an expensive thing.

Mr. BOTLEY: As regards the question of preferring coal gas for industrial purposes, I have a good deal of practice with gas engines, and I have found it requires rather more of the mixed gases than it does of coal gas to get a good result. That may seem a paradox, but it is a fact. It is probably due to the fact that the proportion of air wants to be adjusted for the richer gas, which is of a somewhat different constitution. There is also to be borne in mind that it is much heavier, and that its velocity through an aperture in a given time is more sluggish. That is only my impression; I do not put it forward as an authority. As regards using air, 2 per cent. is the amount we use in the atomiser. You will find in the paper it is mentioned that we are going to use compressed gas. You have got to deduct the oxygen, so it would be proportionately less than 2 per cent. With regard to high flash oil, the circumstances as compared with the ordinary injection of oil are rather different. We do not have quite a closed pipe system, we put our oil into the cylinder direct from the pumps. We had a mysterious mishap, and that perhaps made us a little over-cautious in the matter. If there is any other information required, I shall be only too happy to endeavour to tell any Member what I believe to be correct in the matter.

WIND PRESSURE ON BUILDINGS AND OTHER STRUCTURES.

By J. O. V. IRMINGER, Copenhagen.

In a general way the pressure of the wind is expressed in the force exerted on square feet of surface, the surface in question being assumed to be vertical to the direction of the wind. This pressure is expressed as the normal pressure. If the surface acted on is at an angle to the direction of the wind, various well-known formulæ may be employed, several of which have been independently verified.

Table I. gives these well-known formulæ where the pressure is calculated according to the angle, and where P is the normal pressure.

Many experiments have been made to verify these formulæ, and especially mentioned is Professor Langley, of America, who has devoted much time to the work. He employed a surface of 1 square foot turning on a radius of 30 feet; this surface could be fixed at any angle, and the pressure was measured by a spring. The apparatus had, however, drawbacks, as the air was seldom quite still and the surface of the apparatus warped, but he found that with 5° the pressure on the surface was 0·15 of the normal pressure, with $10^\circ = 0 \cdot 30$, and with $45^\circ = 0 \cdot 93$.

The results coincide fairly well with the stated formulæ, but give a much higher value to the first $\sin^2 a$, often quoted in the technical handbooks. These high pressures at small angles were completely confirmed, which before the experiments of Mr. Langley were a matter of speculation. Pressures on different forms of bodies were not included in Mr. Langley's experiments.

Among other later experimenters, Professor Kernot, of Australia, must be mentioned. He employed for his experiments artificial wind, produced by the aid of a small propellor fixed in a wooden box 10 inches by 12 inches, and the pressure was

exerted on small objects such as cubes, cylinders, &c., fixed in this box, the results being measured by a delicate spiral spring. He expressed his results in proportion to the pressure exerted on a vertical section of the object experimented on. Later, the writer will return to these researches.

All these experiments give the sum of the total pressures, but do not seek to analyse this sum; for instance, the tension of the air on the different portions of the planes and bodies. Generally speaking, the subject has not been a favourite one, and the data on the matter have been of a meagre kind, and at any rate it was only the *pressure on the wind side*, especially at small angles, that was experimented on, the part played by suction being little known.

Herr H. C. Vogt, of Copenhagen, demonstrated some years ago, before Professor Langley's experiments were published, in several "brochures" that the pressure on a plane at a small angle was very great, and he discovered the reason to be, that on the lee side of the plane there existed a strong tendency to a vacuum, and that this partial vacuum or attenuation of the air was equal to 90 to 95 per cent. of the power exerted. Although his arguments were so convincing, his theory found little support, and in fact there were many who were positively sceptical.

As this question interested the writer in no small degree, he determined to carry the experiments further, and as it was soon evident that results of importance were within reach, the research was continued with specially constructed apparatus, and it is the writer's hope that a recapitulation of these results may not be without interest to those who have not had the opportunities of previously studying the subject.

To study the pressures and vacuum exerted on a plane, such a plane was constructed of tin having a flat surface, but hollow. The interior or hollow room was placed in connection with a delicate pressure gauge, and on the flat surface a little hole was bored so that the outer surface with the hole was likewise in connection with the pressure gauge. By presenting the hole to an air current it was possible to establish the presence of a pressure if the aperture was in the direction of the wind, and a vacuum when the aperture was in the contrary direction, but at the same time it was evident that no reliable results were obtainable as the strength of the wind was so variable.

To arrive at definite results it was therefore necessary to create artificial draught, and this was done by employing a chimney shaft 100 feet high, which was in connection with the retort benches, and which gave about $\frac{3}{4}$-inch vacuum at the base. In calm weather the suction was constant, which was first carefully ascertained. In this manner it was possible to experiment with a powerful draught, but the bodies experimented on were naturally of limited dimensions; at the same time it is a well-known fact that the same laws apply equally to small as well as to larger bodies.

The apparatus used, and which is shown, Diagram No. 1, Fig. 1, consisted of a smooth wooden box 9 inches by $4\frac{1}{2}$ inches, fixed at the base of the chimney. In this box the bodies to be experimented on were placed, for instance, a flat plane. This was of tin, hollow, and perforated with three holes, two at the outer edges and one in the centre. This plane revolves on a central axis, likewise hollow, closed at one end, but in connection with the internal hollow of the plane. The open end was connected to a pressure gauge. It was now only necessary to find a zero, or the atmosphere's tension, and for this purpose a hole was made in the box, exactly over the body to be experimented on; in the hole a tube was fixed, projecting not quite through the lid of the box, and which was connected with the second arm of the pressure gauge. By these means the variation of tension in the box itself and the interior of the hollow plane was ascertainable.

To ascertain the tension in various positions, an indicator and scale was attached to the central axis outside the box. The draught to which the apparatus was to be subjected could be regulated by a valve, attached to the end of the box, the position of this valve being constant under each separate experiment. The normal pressure, i.e. the pressure on a plane, at right angles to the direction of the wind was ascertained by turning the plane with the holes toward the wind and observing the pressure, and then turning the plane 180°, so that the holes were on the lee side. The resultant sum of this ascertained pressure and vacuum, was considered the normal pressure.

It was now apparent that when the pressure, taking for instance a single experiment, is about 0·45 inch water pressure on the front side, the suction or vacuum at the back is 0·62

inch, and the normal pressure 1·07 inch, which represents 5·8 lbs. per sq. foot, equal to a calculated wind speed of 50 feet per second. There were, as previously mentioned, three holes in the plane, these three were experimented on, when the average pressure was ascertained. The holes were now successively shut by sticking-plaster.

As the result of many trials it was evident that the suction power or vacuum was equal to 57 per cent. of the total pressure or power exerted, but for shorter planes, with air on all four sides 45 per cent., which is demonstrated on Diagram No. 1, Fig. 2, where the pressures are indicated by the heights of the water column in the gauge.

If experiments be now made on the plane at varying angles, say 0°, 5°. 10°, &c. (Figs. 3–6). At 0°, suction is evident over the whole surface of the plane. At 5°, on the weather side nil. On the lee side, suction greatest nearest the edge toward the wind. At an angle of 10° it is ascertained that the pressure, on the wind side, is greatest first at the *fore-edge*, while the suction on the lee side increases.

The writer found on those planes filling the width of the box, viz. extremely *long* planes, with 5° complete suction, at 10°, 87 per cent., at 90°, 57 per cent. suction. With *short* planes, at 15° complete suction, at 20°, 94 per cent., at 90°, 45 per cent. One can thus ascertain the pressure on the planes by adding the observed water column heights, and the given pressure in proportion to the normal pressure. The results are tabulated in Table I.

TABLE I.

Degrees.	$P_a = P \sin^2 a$.	Lossl. $P_a = P \sin a$.	Hutton. $P_a = P \sin a \, 1 \cdot 84 \cos a$.	Duchemin. $P_a = p \frac{2 \sin a}{1 + \sin^2 a}$.	Rayleigh and Gerlach. $P_a = p \frac{(4 + \pi) \sin a}{4 + \pi \sin a}$.	Langley. $\frac{P_a}{P}$.	Writer's Experiments. Long Planes.		Writer's Experiments. Short Planes.	
							$\frac{P_a}{P}$.	Suction.	$\frac{P_a}{P}$.	Suction.
								per cent.		per cent.
5	0·008	0·087	0·131	0·17	0·146	0·15	0·23	100	0·12	100
10	0·030	0·174	0·241	0·34	0·273	0·30	0·45	87	0·26	100
15	0·067	0·259	0·350	0·48	0·384	0·46	0·47	85	0·41	100
20	0·117	0·342	0·457	0·61	0·481	0·60	0·48	83	0·52	94
30	0·250	0·500	0·663	0·80	0·641	0·78	0·60	75	0·65	83
40	0·413	0·643	0·834	0·91	0·763	0·89	0·75	67	0·74	74
50	0·587	0·766	0·952	..	0·854	..	0·84	65	0·82	66
60	0·750	0·866	1·012	..	0·920	..	0·90	63	0·90	56
70	0·883	0·940	1·023	..	0·965	..	0·95	62	0·95	51
80	0·970	0·985	1·011	..	0·991	..	0·98	59	0·98	47
90	1·000	1·000	1·000	..	1·000	..	1·00	57	1·00	45

It is thus apparent that the ascertained results compare well with Langley's experiments, and equally well with the majority of the previously ascertained formulæ, especially with Rayleigh's and Gerlach's. Professor Cederblom, of Stockholm, has recently conducted some experiments with pressures on planes turned towards the wind, inasmuch as he employed a very finely graduated and sensitive pressure gauge connected with the holes in the plane. He used natural wind, and ascertained exactly the same pressure and suction as tabulated previously. Professor la Cour, in Denmark, has likewise recently conducted some exhaustive experiments on windmills, and has verified the tabulated results. The writer has reason to believe that the method of his experiments is correct, and that the size of the planes experimented on plays no appreciable part; what, however, is very evident, is the part played by *suction*, especially on planes at small angles.

Experiments were further carried out on various elements, hollow and constructed of tin, but later, for the sake of lightness, of wood bored out; for instance, a sphere, as shown on Diagram No. 3, Fig. 14 (sphere). The results are shown on Table No. II., where the pressure on the wind's direction is expressed by d and p. It is thus ascertainable what power is due to pressure and what to vacuum.

The writer desires to shortly sum up the results of the most characteristic experiments, and draws attention to Diagram No. 2, where the amount of pressure and suction is expressed in measured water column heights. The full lines express the pressure, normal on the surface, the dotted lines the pressure in the direction of the wind. These are found by resolving the pressure into two powers, a vertical (not taken into consideration) and a horizontal one. Taking, for instance, a *long prism*, Diagram No. 2, Fig. 8, pressure is found on the front, and suction on the three remaining sides. The pressure is 95 per cent. of the pressure in a plane of the size of the cross-section of this body, the suction equals 43 per cent. If the *point* of the prism be presented towards the wind, the pressure only equals 0·79 per cent. (Fig. 9).

Cylinder.—This cylinder (Fig. 10) presents some extraordinary conditions, inasmuch as there is pressure up to 35° the rest being suction, the maximum being 70°. Resolving likewise the powers in the wind's direction, the dotted lines

are obtained, which show the pressures and suction. The total pressure being 0·57, suction 72.

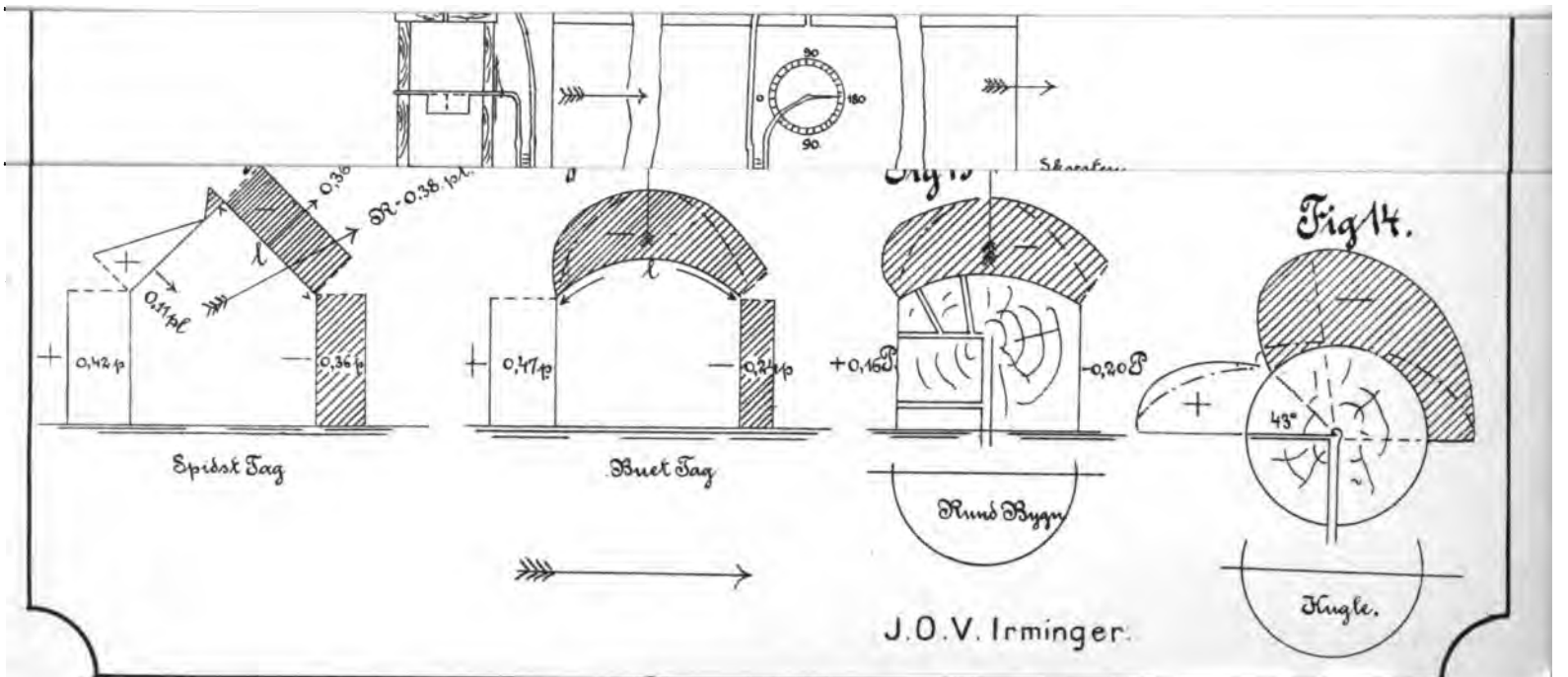
Experimenting on a *prism of rhomboidal form.* The total pressure 0·25, of which suction is represented by 82. This three-sided prism is shown in three different positions. (See Table II.)

On the sphere (Diagram No. 3, Fig. 14) the pressure is found by turning on a lathe a wooden ball, and boring channels for connecting same to pressure gauge. It is then revolved gradually on its axis, and similar effects are found to those on a cylinder, viz. pressure up to 43°, the balance being suction. As the conditions of pressure are alike at same distance from the axis, one can estimate the volume of the body, depicted by the dotted lines which show the horizontal powers; and one finds the total pressure to be 0·31 of the pressure on the great circle.

Under the same conditions experiments were made on *short elements*, such as dice, cylinders, cones, pyramids, &c., &c., the results being tabulated in Table II.:—

TABLE II.

Long Bodies.		Pressure per cent. Wind Side.	Suction per cent. Lee Side.	Short Bodies.		Pressure per cent. Wind Side.	Suction per cent. Lee Side.
—	p = pressure on Square Unit.			—	p = pressure on Square Unit.		
→	$1{\cdot}00\,p\,d$	45	55	→	$0{\cdot}31\,p\,\frac{\pi d^2}{4}$	23	77
Prism	$0{\cdot}95\,p\,d$	57	43		$0{\cdot}08\,p\,\frac{\pi d^2}{4}$	7	93
"	$0{\cdot}79\,p\,d$	24	76	Cube	$0{\cdot}80\,p\,d^2$	78	22
Cylinder	$0{\cdot}57\,p\,d$	28	72	"	$0{\cdot}66\,p\,d^2$	45	55
	$0{\cdot}25\,p\,d$	18	82	Cylinder	$0{\cdot}47\,p\,d^2$	50	50
	$0{\cdot}59\,p\,d$	58	42	Pyramid	$0{\cdot}78\,p\,\frac{d^2}{2}$	63	37
	$0{\cdot}71\,p\,d$	63	37	"	$0{\cdot}55\,p\,\frac{d^2}{2}$	45	55
	$0{\cdot}42\,p\,d$	14	86	Cone	$0{\cdot}38\,p\,\frac{d^2}{2}$	50	50



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The results of experiments on the cylinder give the smaller number, 0·47.

On a pointed element ⬭ only 0·08, of which suction = 93 per cent.

For comparison's sake it may be noted that Professor Kernot found—

For cubes . . .	0·9	The writer . .	0·8
„ cylinders and cones .	0·5	„ cylinders .	0·47
		„ cones .	0·38
„ spheres . .	0·36	„ . .	0·31

It is evident that the results agree fairly well, especially when it is taken into consideration that two distinct methods of experimenting were employed.

These sucking actions on flat surfaces parallel with the direction of the wind are remarkable, but experiments easily establish the facts. For instance, by taking two pieces of paper, holding them parallel to each other and blowing between them, they are drawn together.

On spheres, the sucking action was evident on all the sides the wind passed. It was thus easy to explain why a light ball could be held suspended in a vertical air stream, because the stream was creating a vacuum around the ball. An umbrella ascends vertically when released in a storm, &c. By the same reasoning the trick of blowing an egg from one cup to another is explained.

It is now of interest to obtain the result of these conditions applied to buildings, and the writer has therefore conducted some experiments with models. (See Diagram No. 3.)

The one is a model of a house with an ordinary roof, the other with a semicircular roof; with the first (Fig. 11), the results were precisely the same as those obtained from a prism, i.e. pressure on the wind side, diminishing in an upward direction, and suction on the lee side. Adding together these powers, a result is found in an inclined upward direction per square unit = 0·38 × wind's normal pressure.

On the other building (Fig. 12), the result was the same as with the cylinder, i.e. a suction on the whole of the roof surface, and a resultant directly upwards per square unit = 0·36 × wind's normal pressure.

Further, experiments were made on a round building, with a curved roof similar to a gasholder (Fig. 13), channels for connection with pressure gauge were bored in the model, as shown

on the drawing, the result being a pressure on the side = 0·36 × wind's normal pressure on the cross section, but on the crown a suction in a vertical direction per square unit = 0·43 × normal pressure. On the sides the distribution of pressure is the same as on the sides of the cylinder, and on the roof or crown the same as on the upper roof of the sphere, previously referred to.

The roof on such buildings has thus a tendency to be lifted into the air in a storm when the weight is insufficient or the roof is insufficiently tied to resist this tendency. The experiment on a gasholder can be amplified by suspending a little gasholder model at one end of a lever arm, and submerging the same in a basin of water, so that only the roof of the holder is above the water. If one blows on the roof with a bellows, the holder will lift itself from the water and the pressure in the same be reduced.

It is of further interest to enquire if these experiments have direct relations to what passes on a larger scale, when buildings are subjected to a heavy storm. It may be remarked that one often hears of roofs being lifted and carried away by storms. It is of not frequent occurrence in Europe, and if such an event does happen it is usually with light roofs, and it is likewise established that it is generally the lee side which suffers, in as much as that it is *sucked* away. The writer has made observations on roofs during a storm, by boring small holes in the slates which holes have been placed in connection with a pressure gauge, and the pressure and suction conditions established by experiments were clearly present, varying with the wind's strength.

With a gasholder, the experiment was likewise made during a storm, to connect the outlet pipe with a self-registering pressure gauge. The holder contained two million cubic feet and was 170 feet diameter by 90 feet high. During an exceptionally heavy storm, 30th March, 1897, the pressure in the holder sank from 6·25 inches to 5·83 inches, or 0·42 inches, varying continually with the strength of the wind. The holder was quite full, and gave in calm weather 6·25 inches pressure. This 0·42 inch is equal to a lifting force of 2·1 lbs. per square foot, or 44,000 lbs. on the total surface of the roof. Applying the formulæ found by experiments $2·1 = 0·43, p = 4·9$ lbs. per square foot, which represents the wind's most powerful

impact on the roof of the holder. The pressure on the side of the holder was $0 \cdot 36 \times 4 \cdot 9 \times 15{,}000 = 26{,}600$ lbs., of which 11,800 lbs. was the pressure on the wind side, and 14,800 lbs. suction on the lee side.

Referring to informations obtained from the Meteorological Institute in Copenhagen, where the wind is measured with a self-registering pressure gauge, the wind varied on the occasion named from 29 feet to 70 feet per second. This pressure appears to be very low, but in reality the wind pressure on a large surface is never so great as estimated, on account of the great irregularity of the wind's speed.

The variation has been especially studied by Professors Langley and Marvin of America, and it has been demonstrated, that even on high places lying unsheltered, the wind varied incessantly.

Mr. Langley noted variations of from 9 to 36 miles per hour, and ascertained that taking the average of the maximum and minimum variations, the speed varied 10 miles each ten seconds. The speed would suddenly vary from 40 miles an hour to 0, but there were innumerable variations.

Mr. Marvin discovered similar variations, and at the Copenhagen Meteorological Institute (where the wind speed is measured by current passing over an open vertical pipe, in which the contained liquid is raised by the rarefication or suction caused by passage of the wind) results of a like nature were observable.

Sir J. Wolfe Barry, the engineer of the Tower Bridge, read a paper last year before the British Association,* in which he explained that, after the destruction of the Tay Bridge, the Board of Trade issued instructions to the effect that all future calculations were to be made on a basis of a pressure of 56 lbs. per square foot, instead of the 40 lbs. as previously calculated, and he further remarked:—

"I have been able to carry experiments further at the Tower Bridge by observing the pressure on the surface of the bascules of the bridge, as evidenced by the power exerted by the actuating engines. In this case we have a wind gauge of some 5000 feet in area, and it has been shown that, while small anemometers placed on the fixed part of the bridge register from 6 lbs. to 9 lbs. per square foot, the wind pressure on the

* 'Journal of Gas Lighting,' Sep. 13, 1898.

bascules is only from about 1 lb. to 1½ lb. per square foot. It is difficult to imagine the amount of money which has been wasted in unnecessary provision against wind strains of 56 lbs. on large areas, in consequence of this hurried generalisation of insufficient data. I know something of what the provision for 56 lbs. on the square foot for wind cost at the Tower Bridge, and I do not wish to mention it. But if the public had been told that the dictum of experts, arrived at however hastily in 1880, was to be set aside in the construction of that bridge, all confidence would have been destroyed in it beforehand, and I suppose no Committee of Parliament would have passed the Act."

Here the pressure per square foot is even less than that ascertained by the writer during a storm, viz. 4·9 lbs. per square foot, perhaps on account of the area of the gasholder being three times as large.

The writer once, under a storm, tied a large gasholder, 120 feet diameter, fast to a column on the wind side with a thin cord. The cord held for half an hour and eventually broke; it was confirmed by testing the breaking strength of the cord that the wind pressure was only 3 lbs. per foot. A communication on this subject was sent to 'Journal of Gas Lighting,' 4th May, 1897. If one really wishes to become acquainted with the force of the wind, then America is the place to visit.

Mr. J. Baier, an American engineer, has published the results of some enquiries on wind pressures in the 'Proceedings of the American Society of Civil Engineers,' January 1897. These statistics are voluminous, and are accompanied by many photographs which depict ruined structures which have the appearance of having been submitted to the effects of fearful earthquakes. The writer will dwell shortly on several of the items which are of special interest, and which are closely allied to the subject under discussion.

In St. Louis—the 27th of May, 1896—a tornado demolished, in the course of half an hour, something near to 7263 buildings, of which number 321 were totally razed to the ground. At the same time the new large St. Louis iron railway bridge was ruined, 252 lives were sacrificed, and the monetary loss amounted to three millions of pounds sterling. The buildings for the major part were built of iron and stone. To quote an instance of the storm's severity, it can

be mentioned that the railway bridge was ruined by the wind lifting a portion of the track weighing 280 tons quite away, at the same time demolishing the brickwork. Enormous steel beams weighing 13,000 lbs. were flung 120 feet away. The railing of the bridge flew 1300 feet distance from its original position, and it was proved that the wind exerted a lifting force on the roadway of the bridge of 43 lbs. per square foot. The loosened portions of the bridge were hurled through the air similar to projectiles; one wood planking was thrust through an iron plate $\frac{5}{16}$ inch thick. A large corn elevator, of wood, weighing 3500 tons, was removed 19 feet and crushed. Another even heavier elevator was pushed 11 inches to one side, but again blown back. This is enough to show the appalling power that had been raging.

The storm exerted its force mostly on the upper stories, where the roofs were lifted off and flew away, with the consequence that the walls collapsed. It was estimated that the wind force equalled 120 miles per hour, about double the speed known in Europe, and equal to four times the force.

The upper story of the Meteorological Institute was blown away, and many of the instruments followed suit, but with true American energy the observations were continued as well as possible under the existing conditions on the lower floors.

Mr. Baier found that, on estimating the stability of the structures, the force exerted on and in the destruction of the St. Louis bridge must have been 60 lbs. on the square foot, and the power which removed the corn elevators 20 and 40 lbs. on the square foot.

Such a hurricane simply razes all and everything in its path, but is fortunately not known in Europe; and if we assume that the forces mentioned by Mr. Baier are correct, it cannot be wondered at that the forces estimated in Europe are considerably less violent.

Mr. J. Baier has further inquired into the reasons for these tremendous effects of storm, and is convinced that a great portion of the destruction is due to the constant variation in the speed and strength of the wind, by which great differences in pressures are established in the interior and exterior of buildings, which pressures have no time for adjusting themselves in a natural manner, but break through windows and walls, seeking adjustment by the shortest way possible. A considerable por-

tion of the damage is likewise due to the previously explained *suction* on the lee side of buildings and structures. Mr. Baier goes deeply into these matters, as the results have been published in America; and he mentions that unexpected results have been arrived at, especially regarding the powers of suction, which may thus be regarded as a known phenomenon.

When the wind has a speed of 90 miles and a variation of 120 to 160 miles, such a wind will, according to experiments, when it rushes across a building, exert a lifting force of 20 to 40 lbs. per square foot, without giving the pressure time to adjust itself.

Finally, Mr. Baier says, "The results of these experiments show that the wind acts in a direction quite different from that generally assumed, and usually provided for in designing bridges, roofs, and buildings. The evidence at St. Louis confirms this conclusion."

One may thus assume that the experiments on the small models have been verified by Nature itself, and that calculations of the wind's force must be made on a different basis than hitherto, inasmuch as, besides the horizontal effects, the upward force must be taken into consideration, the power of which can equal half the power of the wind's normal pressure.

DISCUSSION.

The PRESIDENT: I need hardly say we are greatly indebted to Mr. Irminger for this very original paper. He has come a long way to read it to us. There is a story that a man is no prophet in his own country, but I can assure you that in matters of this description Mr. Irminger is a prophet in his own country; and now he has come to prophesy to you. He has studied wind pressures for many years; he has made many experiments, and what he has arrived at, concerning the effect of the wind upon gasholders, is most noteworthy. I am sure he will be only too pleased to answer any questions, or to show you the methods upon which he has conducted his experiments. They are all so simple that you can verify them with little trouble.

Mr. G. E. STEVENSON: I have had the very greatest pleasure in listening to this paper of Mr. Irminger, and I feel myself

very gratified that he has been so ready to become a useful and an ornamental member of this Institution, inasmuch as he has given us a paper at the very first meeting he has attended. I had the honour to propose Mr. Irminger as a Member last year. Such a paper as this we have just heard read we have not had for many years, but it is the kind of communication we want. We are a body, not only of gas makers, but of civil engineers to a large extent, and it is very desirable that the higher elements of the engineering sciences should not be forgotten in our meetings, but should receive the attention they have done in this paper. The paper is most interesting, showing how easy it is for us to be for long periods under mistaken ideas as to the forces and effects of natural phenomena. As Mr. Irminger shows, the effects of wind pressures have been studied from the point of view of preconceived ideas, and except when great catastrophes have called the attention of engineers to the question, very little seems to have been done by investigation to prove whether the established ideas were correct or not. As to the form of roofs, for instance, the idea that a gable-ended roof should be one that is stronger for resisting wind pressure seems in the light of Mr. Irminger's investigations to be ridiculous now. And, moreover, the practice, based more upon experience than scientific study, seems to show us this, because in many countries, where tornadoes are of frequent occurrence, the roofs are flat, but protected by high parapets in such a manner that the wind cannot get under them. We know that a building that has an open end, with a large roofed-over top, is more likely to be destroyed by a gale than one which is entirely closed in, and that, of course, must be due to the great lifting force of the wind by suction. There is one little matter I am not quite clear about myself, and I should be very glad to have it cleared up in my mind. When Mr. Irminger says that so much percentage of the total pressure is pressure, and so much is suction, does he mean that the actual wind pressure is 100 per cent.? Does he mean there is anything beyond the actual wind pressure as measured by the anemometer, or that so much of it is suction, or that there is, in addition to the wind pressure as tested by the anemometer, a suction which makes the total greater than we thought it to be? Apart from that, if the anemometer can show correctly what is the total wind pressure, then comes the question whether if a

great portion of that is suction, and has an upward tendency, in what direction has it to be provided for? In that respect I think these investigations of Mr. Irminger will be found extremely useful to those who have to design gasworks. I wish to express my appreciation of the paper in every sense of the word.

Mr. W. H. Y. WEBBER (London): Mr. President, I wish to contribute my meed of praise to Mr. Irminger for this most admirable paper, which, I think, focuses in a very convenient form—a useful, appreciable form—some certainly new information respecting wind pressure; and summarises a good deal of information which has been floating about, and otherwise only accessible to those who might take the trouble to look it up. This is, the matter of the way in which the wind acts—I think that is the point on the paper rather than the pressure of the wind—the way in which the wind acts upon a structure, and it is due to Mr. Irminger's credit that he has succeeded in making it very clear that the action of the wind, whatever may be its measurable value in weight upon structures, is different to what is generally believed. As Mr. Stevenson puts it, we have had preconceived ideas on the subject. It is scarcely necessary to remind a scientific audience that the "preconceived idea" is the enemy of all truth and progress. It is one of the things to which human nature is very prone; we are all likely to look at things in the light of preconceived ideas. Some years ago, when I first had to look into this matter, I was amazed. In applying the usual formulæ of wind power and resistance to certain structures, the wonder to me was how they stood. Of course I came to the conclusion that there must be something wrong about the formulæ, and that there are other forces acting in a way which were not understood, and that the forces which we thought we knew of did not act in the way in which we imagined. And in the case of gasholders, in which we are most interested, I came to the conclusion that the great thing to do with a gasholder is to hold it down, not so much to hold it up. That, I believe, is the key to safe construction against the pressure of wind—it must be largely a question of holding down. I was confirmed in that view by a little observation I made about two years ago. I was in the country, and an old friend of mine had recently put up on the top of a hill a water reservoir, which he had covered with corrugated iron. Now, that corrugated iron reservoir cover was very well put on, and the top of the

reservoir was only about 6 or 8 feet above the level of the soil, and it was made to arrest the eye or catch the wind as little as possible. The idea was that of a sunken battery in military engineering. Grassed slopes led up to it, and the whole thing was almost buried. The projection of the corrugated iron beyond the walls, to allow the drip, was only a matter of an inch, and it was quite closed in. There was no means of wind getting under it. Well, there came a gale, and the whole of that roof was carried off and deposited in the adjoining field. It was clear that what destroyed that roof was lifting, and not wind pressure at all. My friend said, it went like a card would be shied. It did not occur to me at the time to ask him whether it was held down, but I did afterwards. As a matter of fact, he, not being an engineer, had forgotten to fasten it down; he considered the thing was so snug there was no reason for the wind to carry it away. I think we must remember an observation of the American engineer, that when the wind is blowing very hard, there is a tremendous amount of oscillation going on. The wind does not blow with the same pressure from one half-minute to the other, and there is a tremendous effort towards an equilibrium, which tends to the blowing up just as much as the blowing down of structures. I think the civil engineering profession is much indebted to Mr. Irminger for the careful, conscientious and really luminous way in which he has elucidated this question.

Mr. J. W. Helps: I should like to give one experience that came before my notice a short time ago. In a very heavy storm in February last, one of my workmen told me what happened to the roofs of two houses near to where he lived, and he assured me that those roofs were bodily lifted off their supports and deposited in the garden by his side. I was inclined to laugh at him, for I did not think that roofs could sail in the air. I, looking only at the pressure side of the question, thought they would be pushed down and that part of the walls would come down with them. I think the manner in which this subject has been brought before us to-day will enable us to understand a great many matters connected with wind pressures that we have not understood before. It has often puzzled me as to how the first slate comes off a roof. You have a closed roof and the wind going across it with an immense velocity. If what Mr. Irminger says is correct, that

upward sucking action lifts off the first slate, and the others follow as a matter of course. With regard to the wind pressure upon gasholders, I think that any engineer who has fixed at the outlet of the holder an ordinary self-registering gauge, and has noticed it in a heavy gale will quite appreciate what Mr. Irminger has said, that the pressure varies on an average from 6·5 to 5·8 inches. During the gale I have mentioned I particularly noticed the indications of the automatic pressure register, and I noticed that there was a variation and drop in the pressure equal to 3·10 lbs. to 4·10 lbs. during that night. I wish to add my thanks to those who have spoken, and add my testimony to the value of the paper. I hope we may have a few more like it in the future.

The PRESIDENT: Some of us sail a great deal, and we know that the wind pressure on a boat when close hauled is very little at the masts, and it has been a matter of speculation among sailors as to what makes the boat go forward. The lateral resistance of the water has a tendency to drive the boat forward, but it seems to me this paper elucidates much of what we have been endeavouring to ascertain for many years past—that the force exercised at an angle of say 4 or 6 degrees to the wind, as indicated in the diagram, effects at the backs of the sails a vacuum which drives the boat forward. But when translating this paper I could not help laughing occasionally when I thought of some of my good friends who have large telescopic gasholders and what must their feelings be when they find out that it is not the force of the wind which will turn them over, but one fine day they will find their top compartment sailing over into their neighbours' gardens.

Mr. J. O. V. IRMINGER (Copenhagen): Permit me to return my hearty thanks to Mr. Stevenson, Mr. Webber and Mr. Helps. With regard to the gasholders, it is of course necessary to have supports on account of the horizontal pressure of the wind. With regard to Mr. Stevenson's remarks I will give an example. Mr. Stevenson asks me in what manner I would calculate the pressure. Taking, for instance, a sphere with a cross-section of 10 square feet and the wind pressure 12 lbs., the pressure would be 120 lbs. Then the total pressure on the sphere is 0·31 multiplied by 120, that is about 37 lbs. Of these 37 lbs., 23 per cent. is the pressure on the wind side, and the 77 per cent. is the suction on the other side.

APPENDIX.

DESCRIPTION OF THE BERLIN GAS-WORKS.

(1.) Municipal Works in Gitschinerstrasse.
(Drawings 1 and 2.)

The works are situated so that the coal can be carried into them both by water and by rail. The railway siding in Gitschinerstrasse, connects the works with the "Schlesiche Bahnhof" (Silesian Railway Station). The coal can be stored either in the open air or in the two coal sheds situated opposite to the retort-houses. Out of the two retort-houses, No. 1 is fitted with five double rows of furnaces, arranged vertically to the longitudinal axis of the retort-house and situated in couples placed back to back. In retort-house No. 2 the furnaces are placed parallel to the longitudinal axis of the building. In retort-house No. 1 the furnaces are charged by hand, while in No. 2 they are partly charged by hauling and charging machines worked by electricity. The number of furnaces existing in the works is 107, and of retorts 931. The various apparatus following the furnaces, and more fully specified above, are all located in brick-work houses indicated in the plan of situation.

The works are equipped with three gasholders capable of holding altogether 43,600 cubic metres, while the gasholder installation in Fichtestr., which belongs to the Gitschinerstr. Works, and to which part of the gas produced in these works is transferred, has at present three gasholders with a total capacity of 96,900 cubic metres. The fourth gasholder, now in course of construction, of 47,000 cubic metres capacity will be taken into use next year.

During the working year 1898-99, 110,650 tons of coal were carbonized in the Gitschinerstr. Works, yielding an output of 32,048,000 cubic metres of gas.

(2.) Works near Schmargendorf. (Drawing No. 3.)

The coal is received by the works from Halensee Station of the Berlin Circle Railway, on overhead railway sidings. The coal-shed is situated on one side of the railway siding, and the retort-house on the other side thereof. In the latter the rows of furnaces are arranged

parallel to the longitudinal axis of the building; the furnaces have partly horizontal and partly inclined retorts. For feeding the latter a mechanical stoking arrangement is provided. The coal having been broken up by breaking apparatus, it is raised in iron trucks by hydraulic lifts, to the level of the upper working floor, whereupon these are pushed by hand along narrow-gauge tracks to the back of the furnaces and emptied into iron coal bunkers, from which the coal slides into portable charging boxes (mounted on wheels) which are arranged like those in the Müllerstrasse Works, and which discharge their contents into the inclined retorts. The furnaces with horizontal retorts are worked by hand. Altogether there are 40 furnaces with 360 horizontal retorts and 20 furnaces with 180 slanting retorts.

In connection with these works there is a gasholder branch in Augburgerstr. In order to pump the gas over to the latter a similar plant has been erected as in the Danzigerstr. Works, but on a larger scale. The transferring main has a diameter of 840 mm.

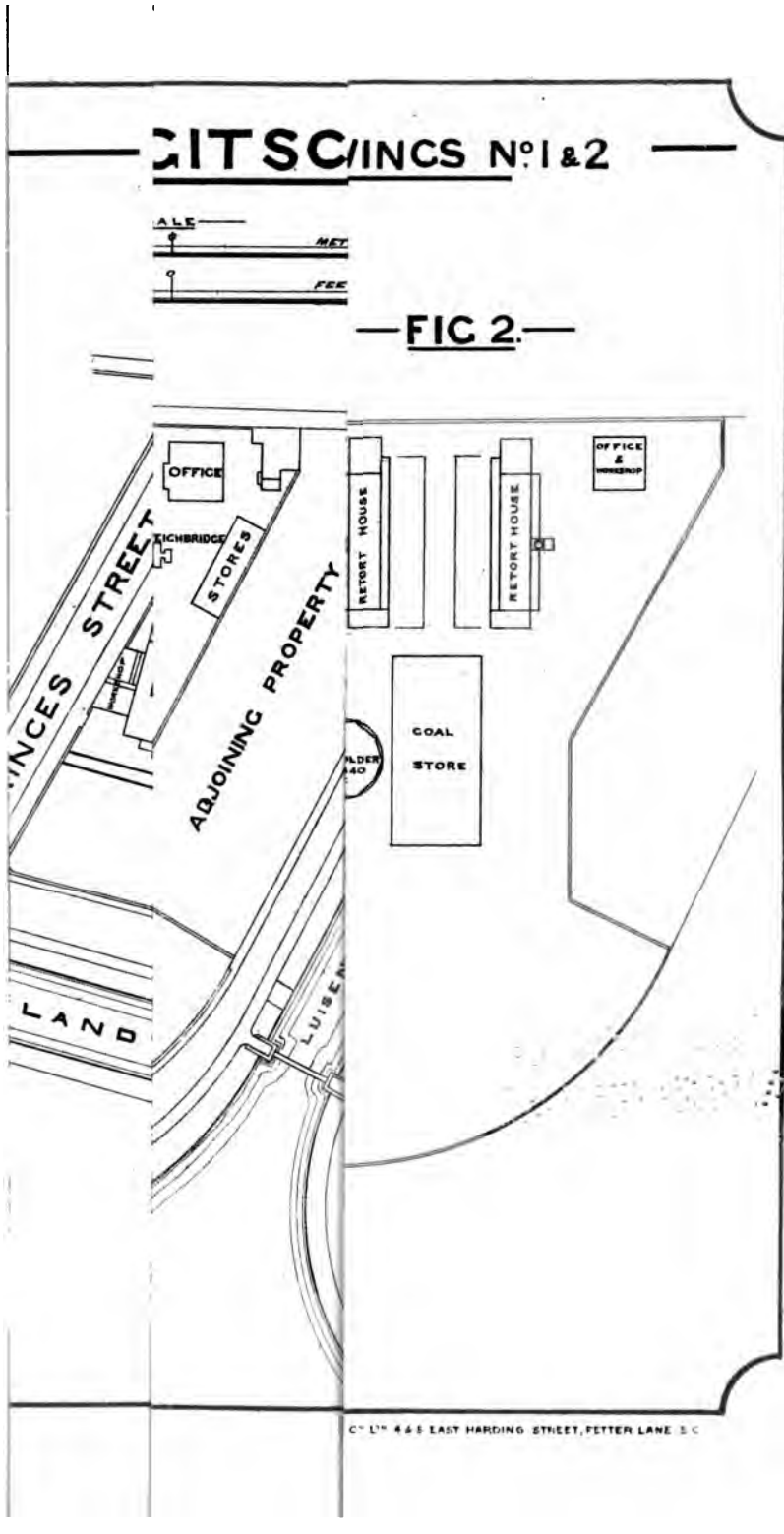
The works have one gasholder of 81,000 cubic metres capacity, and the Augsburgerstr. Branch likewise one gasholder of 81,000 cubic metres capacity.

The works as well as the branch is capable of enlargement up to a capacity of about 400,000 cubic metres per day.

During the financial year 1898-99, 60,634 tons of coal were carbonized, yielding 17,298,000 cubic metres of gas.

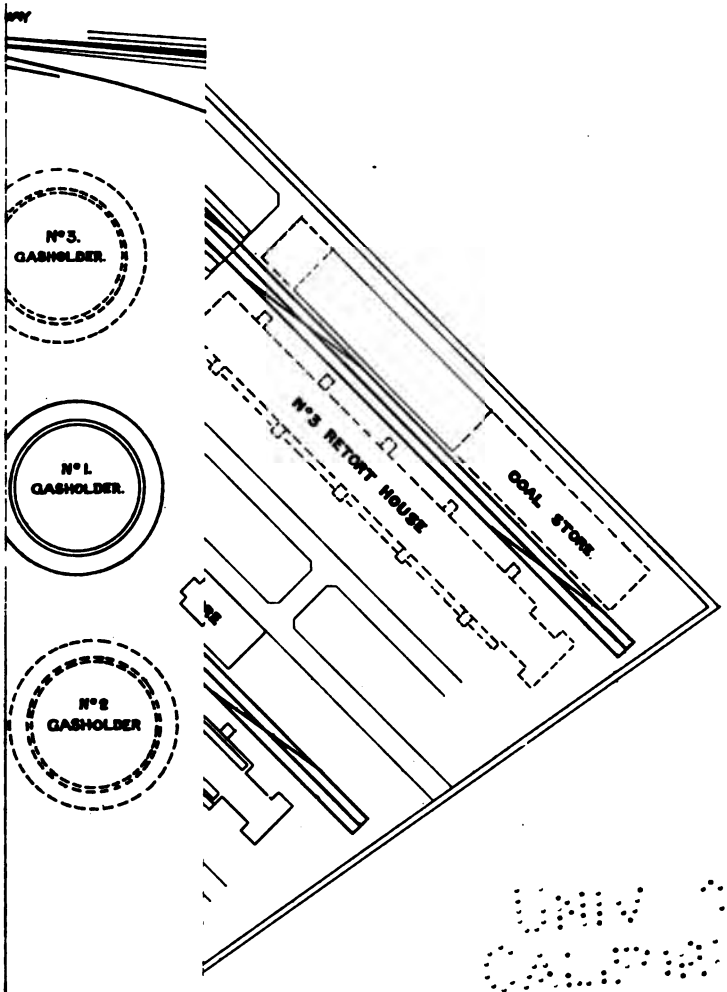
The total output of gas in all the Berlin Municipal Gas-works taken together, was 128,140,000 cubic metres for the working year 1898-99, as compared with 121,747,000 cubic metres for the preceding year, being an increase of 5·25 per cent.

The works in Stralauerplatz, which ceased to be in use on the 1st of April of this year, participated in the past financial year 1898-99 in the total output, to the amount 6,924,000 cubic metres, and carbonized 24,175 tons of coal.



GITSC/INCS No. 1 & 2
ALE
MET
FEE
FIG 2.
OFFICE
TICHBRIDGE
STORES
INCES STREET
ADJOINING PROPERTY
RETORT HOUSE
RETORT HOUSE
OFFICE & WORKSHOP
COAL STORE
LAND
LUISEN
C^o L^TD 4 & 5 EAST HARDING STREET, FETTER LANE S.C.

RF. — — DRAWING Nº 3



UNIV. OF CALIFORNIA

DESCRIPTION OF THE NEW FREDERIKSBERG WORKS OF THE DANISH GAS COMPANY.

COMMUNICATED BY F. D. MARSHALL.

THE works were commenced in the spring of 1895. The time occupied in building operations being about ten months. The old works were laid off on the 14th December, and the new ones started immediately with almost the maximum winter consumption.

The coal-storing machinery has been described in the Proceedings of the Institution. The coal is stored preliminarily at the Coal Company's wharf at the Free Harbour—the arrangements have been inspected by the Members—and is transported as required to the gas-works. One train daily carries 100 to 200 tons.

At the gas-works 1000 tons are stocked in the "Monier" pockets or bins. The storing of and emptying the bins is performed mechanically at the rate of about 120 tons per hour, the two actions taking place, if need be, simultaneously. Two to three men only being required to handle 120 tons per hour. The coal hoppers in the retort-house are filled every evening at 6 P.M., so that no coal-handling is done at night. The coal-storing plant has now been at work for four years, and apparently with a minimum of wear and tear.

The retort-house is fitted with 153 12-feet inclined retorts, equal to a maximum daily production of about 1,200,000 cubic feet. The retort-house under construction will be fitted with seventy-two 16-feet retorts, and is estimated to produce about three-quarter millions per diem.

The coke will be transported to the existing steam-crushing machine by a De Brouwer conveyor.

The condensing is effected entirely by water-tube condensers, the water for the same being abstracted from and returned to the gas-holder tanks. It is pointed out that no apparatus or pipes of any description are exposed outside buildings, and pipes of every kind are accessible in cellars or culverts. The tar is abstracted by special tar extractors placed in the condenser-room. These are fixed after the exhausters. The tar tank, 80 feet by 50 feet by 10 feet, is perhaps the largest tank constructed on the "Monier" system, and has been described in the Proceedings of the Institution.

The boilers are of the water-tube type constructed in Copenhagen, one 90 horse-power, and two 60 horse-power. Attention is directed

to the water-cleansing apparatus, whereby the boilers are supplied with, comparatively speaking, chemically clean water.

The exhausters require no attendant. The lubricating being effected automatically and the regulating by the beautifully constructed apparatus on the "Hahn" system, to which special attention is directed.

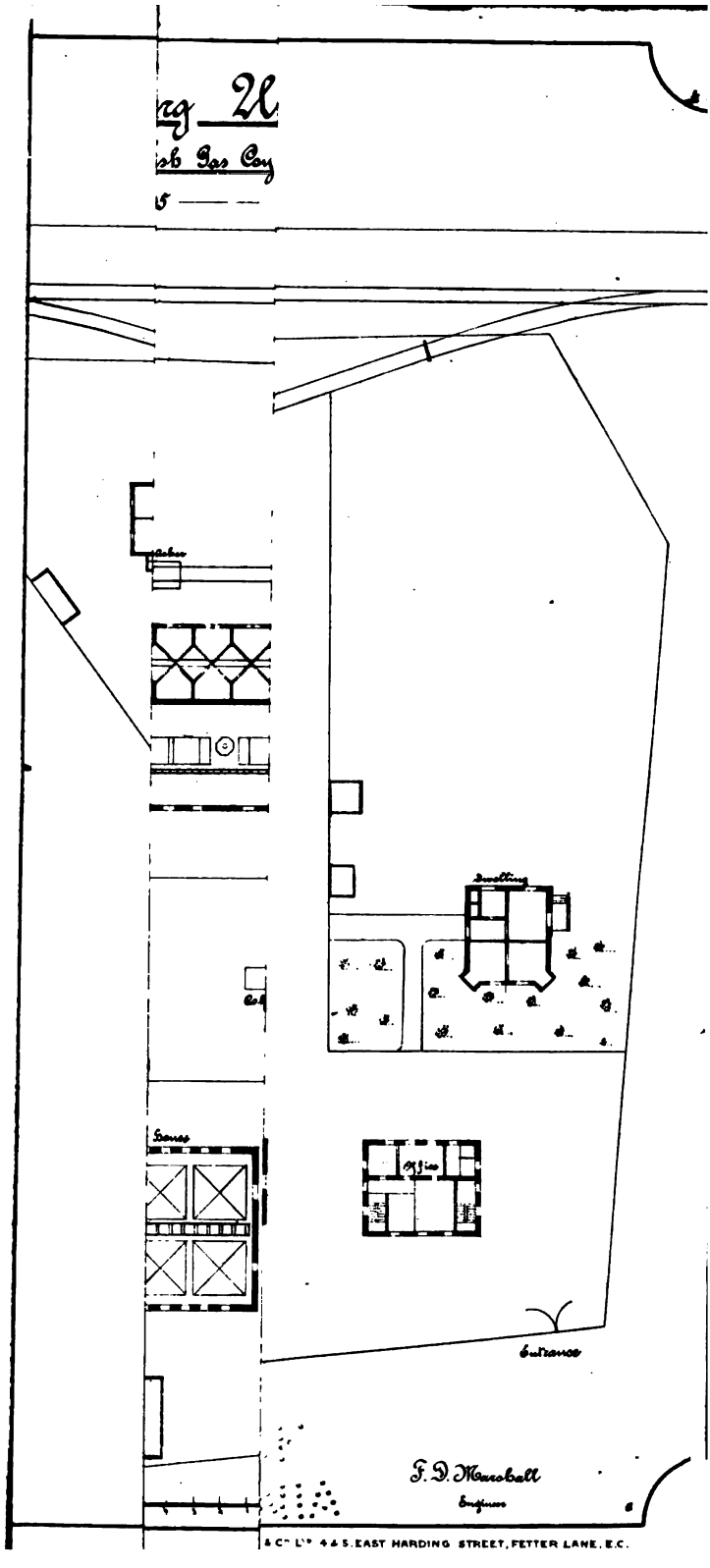
The purifiers are filled by a continuous conveyor passing along the floor of the house, and are emptied by doors in the bottom of the boxes.

The engine driving the coal machinery actuates the oxide elevator.

The Station Governor is on the "Ledig" system, and is worthy of inspection. It is practically automatic, increasing and decreasing pressure in direct accord with the demands of the district. This action is effected by a syphon-arrangement. The initial inlet-pressure to the Governor must be always constant, and this is effected by employing a "Sentinel" Governor, whereby any variation in gas-holder-pressure is adjusted.

The gas is carburetted by a Bunsen carburettor, and is impregnated with alcoholic vapour by the Bueb apparatus.

The offices and Manager's dwelling are heated by air warmed by the slow combustion breeze burning Perret's Calorifere.


rg 2l
sb Gas Coy
5
Dwelling
Houses
Office
Entrance
F. D. Marshall
Engineer
& Co Ltd 4 & 5. EAST HARDING STREET, FETTER LANE, E.C.

DESCRIPTION OF THE EASTERN GAS-WORKS, COPENHAGEN.

COMMUNICATED BY F. D. MARSHALL.

THE coal supply is at present remodelled so that the coal is received from the Free Harbour. The coal is taken from the ship by the aid of two cranes—system "Hunt." Each crane can lift 700 tons per day. The cranes are provided with grabs containing one ton of coal, which is emptied into railway trucks, and transported to the gas-works.

The railroad rises in the gas-works and is carried up to the level of the coal-house roof, the gradient being 1 in 32, and the minimum radius of the curves 80 feet. A locomotive draws six cars, each carrying 6 tons of coal, and two trains do the transport. Along the elevated railway, outside the coal-sheds, are hoppers into which the coal is discharged, and under these hoppers are the automatic cars (System Hunt) which receive the coal and convey it into the coal stores, discharging it at the places desired. A counterweight brings the empty cars back, *in situ* under the hoppers. The coal-houses can contain 40,000 tons and the coal is stacked 14 to 18 feet high.

There are two retort-houses, viz. the old one, worked by hand-power, which has forty generator ovens with one generator for every two ovens—each oven contains seven retorts. The new retort-house is worked by "West's manual machinery," and also contains forty ovens of same construction as in the old house, but each oven is fitted with eight retorts. The two houses are equal to a maximum production of 3¾ millions cubic-feet gas per diem.

The condensers are water condensers erected in a condenser-house, there are twenty of them arranged in five rows, four in each row, each condenser contains 16·4″ water-circulating pipes, through which the water passes in the opposite direction of the gas.

The temperature of the gas at the outlet is about 20° Celsius summer and winter. The circulating water, when leaving the condensers is about 40° Celsius, and is used for the boilers and baths, &c. By the side of the condenser-house is a large tar tank, in which the tar and ammonia water are separated. From the ammonia liquor is produced sulphate of ammonia. Nearly all the tar passes through two centrifugal extractors which separate the liquor from the tar.

The exhausting plant consist of three exhausters; two of a capacity of 150,000 cubic feet per hour, while the third combines

two smaller ones which are driven by the same engine and have a capacity of 80,000 cubic feet per hour.

There are four boilers, in which feed water is purified from lime by the aid of natron.

The tar is separated from the gas by means of three Andouin & Pelouze condensers, each equal to the treatment of three million cubic feet gas per diem.

Two standard washers of same capacity wash the gas free from ammonia.

The purification is done by means of oxide of iron in two systems of purifiers, namely, six of dimensions 20 feet by 17 feet, which are old, and four new ones of dimensions 38 feet by 28 feet. The lids are handled by hydraulic cranes; in order to assist the purification 4 to 6 per cent. of atmospheric air is pumped into the purifiers by the aid of two small exhausters, with meters attached; charging the purifiers is therefore very seldom required. The old purifiers are fitted with "Dry-Centre-Valves," and the new ones with "Hydraulic-Centre-Valves."

There are three gas-holders, one containing 400,000, one containing 600,000, and one containing 200,000 cubic feet gas.

There are two station meters, each passing 3 million cubic feet per diem, and the gas is sent out to the town through two regulators by means of two mains, one of 30 inches, and one of 36 inches diameter.

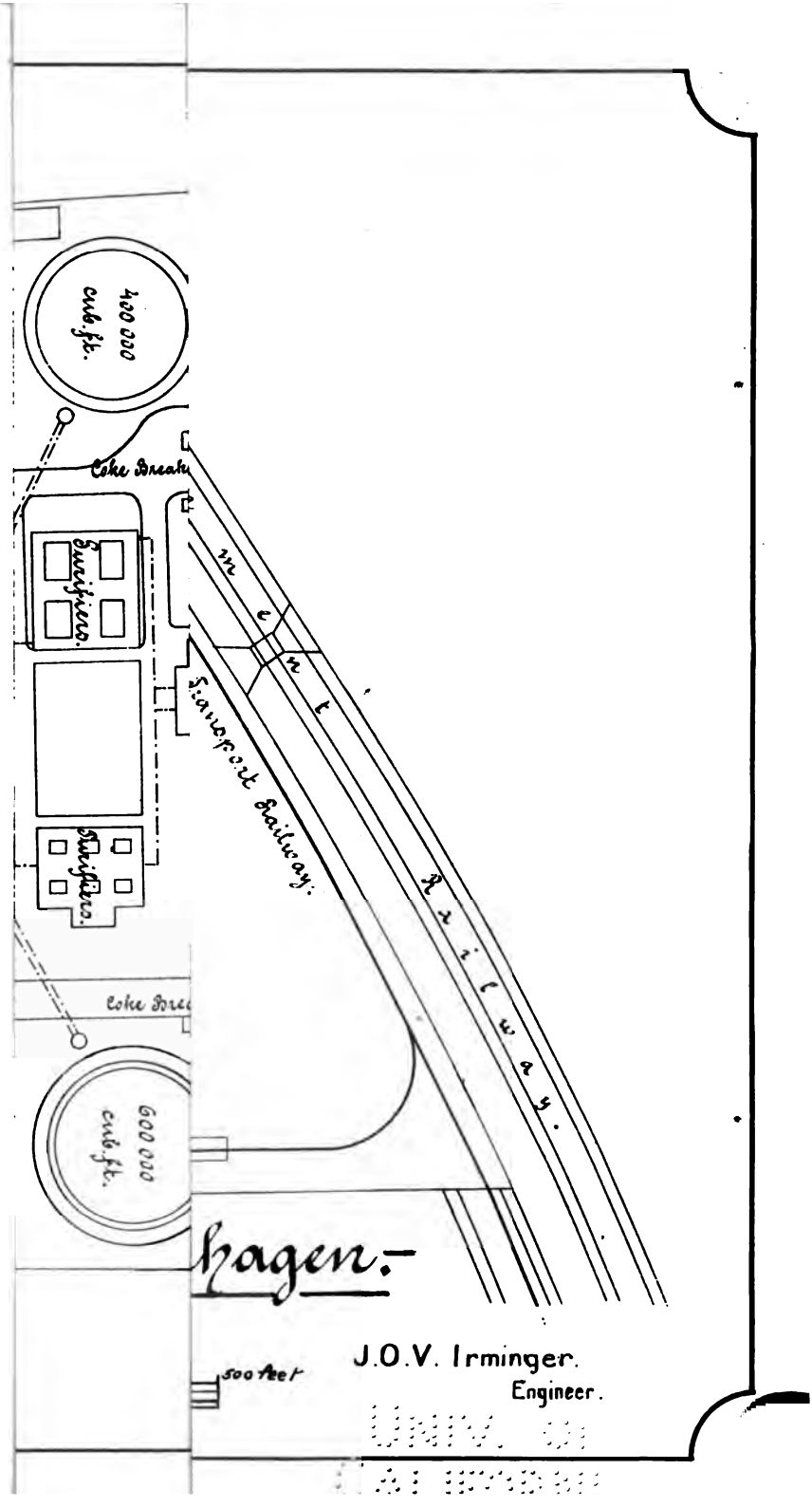
For the treatment of the coke there are two sets of crushing machinery, each consisting of two crushers. By the aid of hydraulic cranes the coke is elevated in cars, and may be sorted or stacked as required. The measuring of the coke is executed automatically.

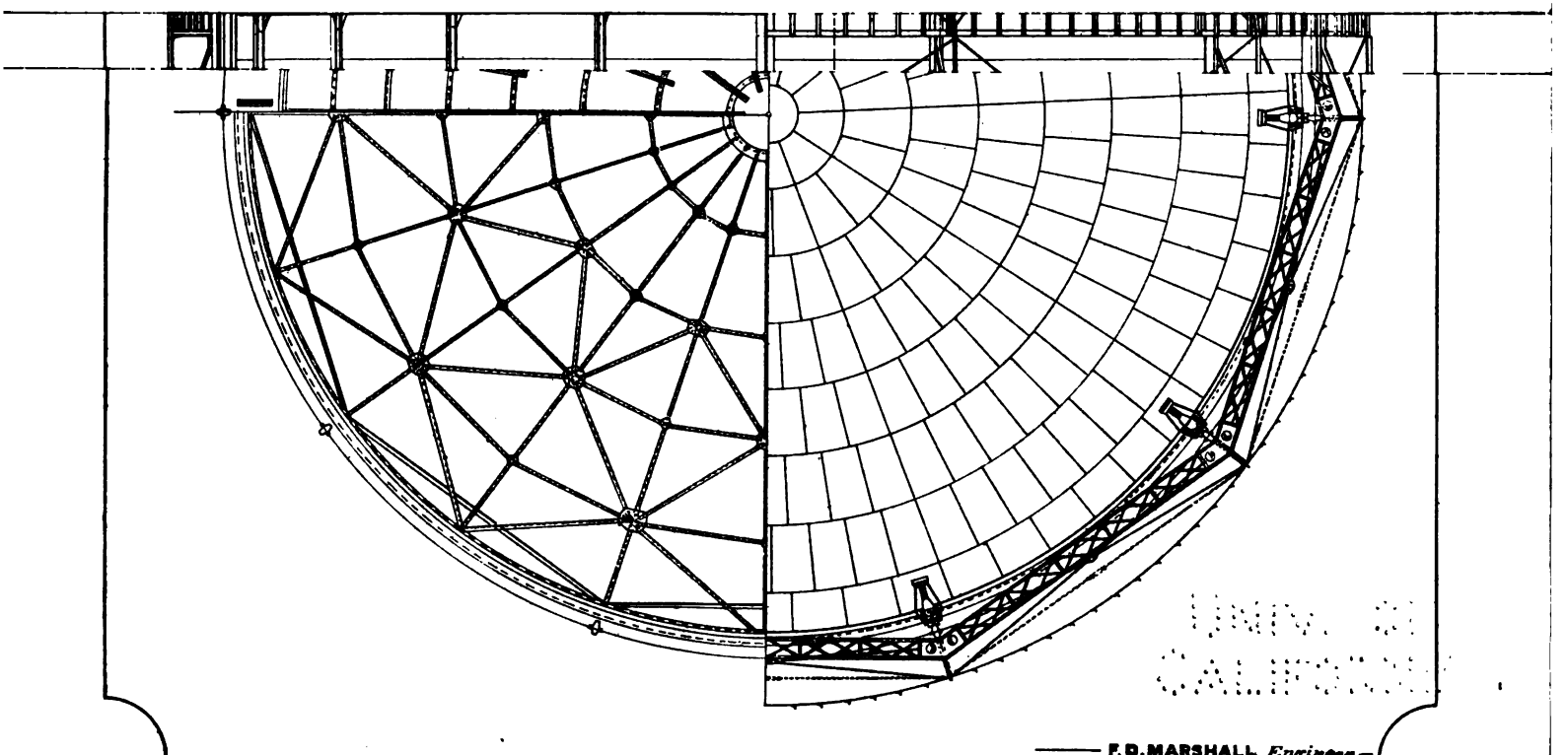
There is now being built a water-gasworks for a production of two millions of cubic feet per diem, with an assisting gasholder of a capacity of 40,000 cubic feet, and an oil tank to hold 1200 tons of oil. The gas will be led from this plant to the condenser, and from here will be sent to the town, together with the coal gas.

For the workmen and stokers are provided several commodious apartments, as well as bathing rooms furnished with warm shower-baths, and lavatories with cold and warm water.

Maximum of gas produced in 1898 was 720 millions cubic feet. The illuminating power of the gas is 15 Hefner candles (14 English), and no cannel is used.

	Cubic feet.		Per cent.
Gas used for lighting purposes	433	millions	34·89
Cooking and motor gas	618	„	49·74
Gas for street lamps	95	„	7·68
Consumption on works	13	„	1·00
Leakage	83	„	6·69
Total	1242	„	100·00


400 000 cub. ft.
Coke Break
Purifiers.
Purifiers.
Coke Brea
600 000 cub. ft.
Transport Railway.
m e n t
R a i l w a y.
hagen.-
500 feet
J.O.V. Irminger.
Engineer.


F.D.MARSHALL Engineer

The increase for consumption for lighting and cooking gas was in 1897 equal to 8·68 per cent.

There is a special price for lighting and cooking gas.

The number of meters fixed in 1898 was:—

For lighting purposes . . .	20,386
„ cooking „ . . .	50 315
„ prepayment meters . .	2392

ABSTRACTS OF PAPERS PUBLISHED IN VARIOUS CHEMICAL JOURNALS.

Incandescent Gas Lighting in Munich. By Dr. E. SCHILLING. (Journal für Gasbeleuchtung, 1898, 397.)

The author states that the installation of the electric light in the principal streets of Munich having given great satisfaction in consequence of the great improvement in the lighting, it was decided to improve the standard of illumination in the whole of the streets of the town. For this purpose the whole of the public lamps (5100 in number, and exclusive of the electric arc lights in the principal streets) in Munich, were fitted up with incandescent burner enclosed in holophane globes.

The renewals since the commencement amount to

Chimneys 2·011 per lamp per annum.
Mantles .. 4·2 „

The total cost of maintenance, including interest and sinking fund charges, amounted to 14*s.* 5*d.* per lamp per burner per annum, with mantles costing 10·2 pence each.

The cost of mantles having since been reduced to 6*d.* each, the present cost is only 12*s.* 8*d.* per annum.

According to the Annual Report of the Munich Statistical Office, the total charge for 830 electric arc lamps in the year 1896, amounted to 22,795*l.*, while 5100 incandescent gas lamps only cost 11,965*l.* for the same period, or 27*l.* 9*s.* and 2*l.* 7*s.* per lamp per annum respectively.—G.P.L.

The Balance Sheet of Heat Units in Coal Distillation. By HERMAN POOLE, F.C.S. (Abstract of Communication to American Gas Light Journal.)

The author commences his communication by stating, that while tests of boiler efficiency are frequently made, practically nothing has been done to test the efficiency of retort settings. Particulars are then given of an actual efficiency test upon a retort setting, in which every care was employed to obtain correct results. The coal was analysed and weighed. The calorimetric value of the coal and the products was actually obtained by experiment and not calculated, and each product was carefully weighed as pure and clean as it could be.

The analysis of the coal showed :—

	Per cent.
Carbon	75·182
Hydrogen	5·176
Oxygen	8·202
Nitrogen	0·940
Ash	7·050
Moisture	3·450
	100·000
Total heat units for the crude coal	13,260

By distillation at cherry-red heat there was formed :—

	Per cent.
Coke	65·66
Tar from hydraulic main	0·87
" " cooler	1·16
" " condenser	1·89
Gas	17·09
Ammoniacal liquor	9·35
Loss, water, &c.	3·97
	100·00

The products yielded on analysis the following composition :—

ANALYSIS OF DECOMPOSITION PRODUCTS.

—	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.	Water.	Calorific Power.
Coke	85·77	0·41	2·04	0·62	10·27	0·88	12,635
First tar	89·91	4·95	5·14	..	..	..	16,097
Second tar	87·22	5·50	6·28	..	..	..	15,896
Third tar	85·18	5·60	9·22	..	..	..	15,369
Gas	55·09	21·46	23·45	..	..	..	20,000
Ammoniacal liquor ..	..	..	..	..	..	..	00,000

The heat values of these different products added together, should equal the total of the original coal. Multiplying the percentages obtained by the respective heat values :—

HEAT VALUES OF DECOMPOSITION PRODUCTS.

Coke	65·66	×	12,635	= 8,296
First tar	0·87	×	16,097	= 140
Second tar	1·16	×	15,896	= 184
Third tar	1·89	×	15,379	= 290
Gas	17·09	×	20,000	= 3,418
Loss	3·97	×	13,260	= 527
Total				12,855
Heat units in coal				13,260
Unaccounted for, 3·05 per cent.				405

In order to split up the coal and produce these various products of the decomposition, force was needed, and all the original force of the coal is retained. This new force must have come from the outside; that is, from the combustion of the fuel in the furnace. The consumption of coke was equal to 21·09 per cent. of the coal carbonised, therefore the amount of heat available was 21·09 per cent. × 12,635 = 2665 heat units. These 2665 heat units then were used in decomposing the coal, forming the new compounds, distilling them, heating them, and also in furnishing the heat lost by radiation, and that carried away to the chimney by the waste gases from the fire. An idea as to the amount of heat used in the decomposition can be had by comparing the actual and theoretical heat units of the different compounds produced:—

COMPARISON OF CALCULATED AND ACTUAL HEAT VALUES.

—	Calculated.	Actual.	Difference.	Percentages.	Total Differences.
Coke	12,632	12,635	3	65·66	0
First tar	15,639	16,097	458	0·87	4·1
Second tar	15,592	15,896	304	1·16	3·5
Third tar	15,150	15,369	219	1·89	4·1
Gas..	19,152	20,000	488	17·09	69·5
		Grand total difference			81·2

The losses from radiation and waste gases can be approximated. The number of heat units carried off by the waste gases can be computed by multiplying the percentage in weight by the specific heats, and then multiplying the sum of these products by the temperature of the gases. Supposing 300 cubic feet of air was supplied per pound of fuel, the composition and heat values would be as the following table:—

	Percentage by Weight.		Specific Heat.		
Oxygen	·1111	×	0·217	=	0·0241
Nitrogen	·7096	×	0·244	=	0·1731
Aqueous vapour	·375	×	0·479	=	0·0179
Carbonic acid	·1418	×	0·217	=	0·0308
	1·0000				0·2459

Assuming the temperatures to be at least 500° F., the units of heat carried off would be 0·2459 × 500 = 122·95 units per pound of gases, and as there are 5·11 pounds of products from 0·2109 pounds of coke 122·95 × 5·11 = 628 units to chimney per proportionate charge of fuel.

The approximate distribution of the heat produced by the combustion of the coke in the furnace is as follows—

Consumed in decomposition	81
" waste gas	628
" radiation..	266
Unaccounted for, and loss in distillation	936
Probable loss from hot gas, &c.	754
Total heat units	2665

Determination of the Vapour Tensions of the Condensable Hydrocarbons in Coal Gas. By WILFRID IRWIN. (Abstract of a Paper read before the Manchester Section of the Society of Chemical Industry.)

The author first directs attention to the *quantity* of condensable products produced per unit of coal carbonised, and cites as an example the following table, giving the yield of the most important bodies capable of being condensed from gas produced by the carbonisation at high temperatures of one ton of Lancashire coals.

—	Boiling Point.	In Gas.	In Tar.	Total.
	Degrees.	lbs.	lbs.	lbs.
Benzene	80·4	18·0	0·8	18·8
Toluene	111	6·0	0·7	6·7
Xylene..	137–142	0·4	1·0	1·4
Cumene	163–169	0·1	0·3	0·4
Naphthalene	218	0·15	13·0	13·15
Phenol	184	..	1·0	1·0
Pyridine (90 per cent.)	120–140	..	0·3	0·3
Anthracene	360	..	0·3	0·3
Phenanthrene	340	..	1·0	1·0
Higher phenols and sundry heavy oils ..	200–400	..	22·7	22·7
Pitch	..	..	93·0	93·0
		24·65	134·1	158·75

Influence of Temperature on Yield of Condensable Products.

The conclusions arrived at by the author upon this point may be conveniently summarised in the following table:—

HIGH TEMPERATURES produce greater percentages of:—	LOW TEMPERATURES produce greater percentages of:—
Hydrocarbons of the aromatic series.	Hydrocarbons of the paraffin series.
Naphthalene.	Sundry heavy oils.
Benzene (at the expense of phenols and paraffins).	Pyridene.
Pitch.	Phenols.
	Cumene.
	Xylene.

Toluene, phenanthrene and anthracene are not materially influenced by changes in temperature.

VAPOUR TENSIONS.

—	10°.	15°.	20°.	25°.	B.P.
	mm.	mm.	mm.		° C.
Benzene	48	61	79	..	80·4
Toluene	..	19·4	..	..	111·0
Xylenes 3	..	6·3	..	..	138·41
Cumenes 3	..	1·5	..	..	163·9
Naphthalene	..	0·03	..	0·08	218·0

From the analysis of the gas recorded in the foregoing tables, it was calculated that—

10·7	per cent.	was saturated with	benzene.
9·5	"	"	toluene.
1·2	"	"	xylene.
1·1	"	"	cumene.
22·5			

Leaving 77·5 per cent. to be saturated with high boiling hydrocarbons.

Naphthalene is the only other substance possessing an appreciable vapour tension, and is present in considerable excess, hence at 15° C., something approaching 77·5 per cent. of the gas is saturated with naphthalene. At 15° C. and a vapour tension of 0·03 mm. it has been found that 10,000 cubic feet of gas contained 0·1 lb. naphthalene.

As only 22½ per cent. of the gas is saturated with low boiling hydrocarbons, there is an extensive field for enrichment, or the mechanical addition of other hydrocarbons, to take the place of naphthalene in saturating the remaining 77½ per cent. of the gas. For this purpose benzole is by far the best method when the gas is consumed in flat-flame burners, but carburine shows up much better in the argand burners usually employed for testing illuminating power in gas-works.—G. P. L.

Depth of Fire in Water Gas Generators. By J. M. Rusby. (Abstract of Paper read before the American Gas Light Association.)

The author records a series of tests on the influence of depth of fuel on the quality and composition of the gas produced, and these are briefly summarised in the following table.

—	Test 1.	Test 2.	Test 3.
Depth of fuel	7′ 0″	3′ 0″	3′ 0″
Duration of "run" in minutes ..	7″	7″	7″
Duration of "blow" in minutes ..	7″	7″	7″–3″
Blast pressure in inches..	7″–8″	4″–6″	5½″
Clinkering	12 hours	7 hours.	7 hours.
Gas made per run (cubic feet) ..	8450	5200–5700	4250
Steam in generator per 1000 cubic feet	32 lbs.	45–51 lbs.	45–50 lbs.
Remarks	Fuel and oil results very uniform and good.	Fuel and oil results inferior to No. 1 Test.	Heats in carburetter and super-heater difficult to control, and oil results very poor.

The runs in each case were alternately up and down.

Holes were drilled in the sides of the generator, and the gases analysed from various portions of the machine during both "runs" and "blows."

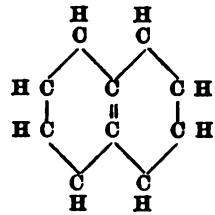
The results indicated that nearly the whole of the carbonic acid produced during the blow was reduced to carbonic oxide at a point 3 feet above the grate bars, and also that the percentage of oxide was greatest with the shortest "blows." With the heaviest blast employed no oxygen could be discovered at 2 feet above grate bars.

It was assumed at the commencement of the experiments, that as an excess of steam was admitted, the percentage of carbonic acid would be lowest at the bottom of a 7 feet fire, and would also be lower (at least at the beginning of a run) with a shallow than a deep fire. Neither assumption was found to be true: the carbonic acid in the uncarburetted gas was found to increase from 2 to 2½ per cent. from the beginning to the end of a seven minutes run. Carbonic acid was materially decreased by shortening the period "blow" and decreasing steam supply.—G. P. L.

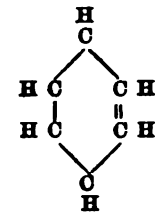
Naphthalene. By Dr. P. Eitner. (Abstract of Paper read before the Mid-Rhenish Association of Gas and Water Engineers. Journal of Gas Lighting, Feb. 21, 1899.)

The author commences his paper by comparing the graphic formula of naphthalene and benzene, and showing that the latter is of much simpler composition than the former, as will be seen from the respective ring chains indicated below:—

Naphthalene ($C_{10}H_8$).



Benzene (C_6H_6).

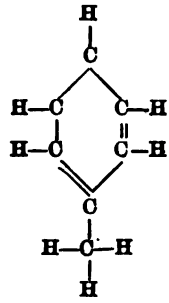


Naphthalene has the larger and heavier molecules, and is richer in carbon, is solid at ordinary temperatures, melts at 80° C. (176° F.), and begins to boil at 217° C. (423° F.). Like benzene it volatilises at ordinary temperatures. Practical research and theory alike show that benzene and naphthalene are not formed after the gas has left the retort, but are produced by changes during carbonisation.

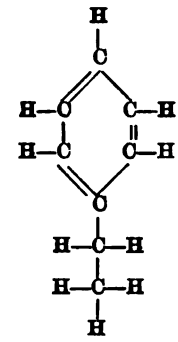
When substances such as benzene, toluene and xylene are subjected to a considerable degree of heat in the retort, many changes take place, and the long chains in the formula are ruptured into fragments, resulting in the formation of simpler and more elementary bodies, which again recombine to form new combinations. Bodies such as toluene and xylene with open chains are much more readily ruptured than those represented by ring-shaped formulæ;

the lateral chains indicated on the formulæ given below being easily torn off or abbreviated.

Toluene.



Xylene.



As naphthalene is one of the bodies represented by a ring-shaped formula, it is comparatively unaffected after being once formed in the retort.

100 parts by weight of gas coal yield :—

Coke	= 68 parts.	
Water (gas liquor) ..	= 10 „	
Tar	= 5 „	containing 6 per cent. = 0·3 parts of naphthalene, also 0·05 parts benzene.
Coal gas	= 17 „	containing 8 per cent. = 1·25 parts benzene.

There are thus obtained from 100 parts by weight of coal 1·3 parts of benzene, distributed thus :—

1·25 parts = 96·2 per cent. in the gas
0·05 „ = 3·8 „ „ tar

and 0·3 parts naphthalene distributed thus :—

Traces = — per cent. in the gas
0·3 parts = 100 „ „ tar.

Coal gas at 10° C. (50° F.) retains :—

	Per cubic foot.	Per 10,765 cubic feet.
Benzene	94·8 grains.	146 lbs.
Naphthalene	0·87 „	1 lb. 5½ oz.

It will be noted from a consideration of the above figures, that nearly the whole of the naphthalene is thrown down out of the gas with the tar, chiefly by the action of the homologues of benzene, which have ring-shaped formulæ with lateral chains attached, and dissolve naphthalene freely. Hence the best remedy appears to be in not using too high heats which tend to dissociate these homologues.

Another remedy lies in the addition of a solvent vapour to the gas, which on cooling in the district mains, will carry down the naphthalene in solution.

The table given below gives the solubility of naphthalene in various solvent liquids.

SOLUBILITY OF NAPHTHALENE AT DIFFERENT TEMPERATURES.

Solvent.	Parts by weight of Naphthalene dissolved by 100 parts of solvent.	
	At 10° C. (56° F.)	At 0° C. (32° F.)
Alcohol	5·0	4·25
Petroleum ether	11·05	7·75
Benzene	40·70	32·00
Toluene	35·30	24·80
Xylene	29·00	20·80

TENSION AT DIFFERENT TEMPERATURES IN MILLIMETRES OF MERCURY.

—	At 0° C.	At 10° C.	At 20° C.
Alcohol	12·0	20·0	43·0
Petroleum ether	58·0	69·0	100·0
Benzene	25·0	49·0	76·0
Toluene	8·5	14·0	23·0
Xylene	3·0	4·2	7·0

The quantity of the various substances to saturate 1 cubic foot of gas is given in the following table.

One cubic foot of Gas takes up of—	At 0° C.	At 10° C.	At 20° C.
	grains.	grains.	grains.
Alcohol	16·02	22·37	47·46
Petroleum ether	137·90	173·71	247·17
Benzene	50·78	94·65	145·39
Toluene	20·32	31·79	51·89
Xylene	7·38	11·06	18·35

If gas is fully saturated at the higher temperature, and is then cooled down, the vapours condense out until the point of saturation at the reduced temperature is reached. The *liquid* which condenses out in this way is *available* for dissolving any naphthalene deposited, but the *vapour* which still remains in the gas has no action whatever upon it.

—	Grains of Liquid which separate out from one cubic foot of Gas when it is cooled.			Grains retained as Vapour at—	
	From 20° C. to 10° C.	From 10° C. to 0° C.	From 20° C. to 0° C.	10° C.	0° C.
Alcohol	25·09	6·35	31·44	22·37	16·02
Petroleum ether	73·46	35·81	109·27	173·71	137·90
Benzene	50·74	43·87	94·61	94·65	50·78
Toluene	20·10	11·47	51·57	31·79	20·32
Xylene	7·29	3·68	10·97	11·06	7·38

—	Grains of Naphthalene dissolved by Quantity of Carburetting Liquid which separates from one cubic foot of Gas.		
	From 20° C. to 10° C.	From 10° C. to 0° C.	From 20° C. to 0° C.
Alcohol..	1·25	0·27	1·31
Petroleum ether	8·12	2·78	8·47
Benzene	20·65	14·04	30·28
Toluene	7·10	2·84	7·83
Xylene..	2·11	0·76	2·28

Carburetting Liquid.	Grains of Liquid with which the Gas must be saturated at 20° C. in order that 100 grains of Naphthalene may be dissolved when the gas is cooled.	
	From 20° C. to 10° C.	From 20° C. to 0° C.
Alcohol..	3758	3549
Petroleum ether	3044	2919
Benzene	705	479
Toluene	732	663
Xylene	869	804

The cost of removing 100 grains of naphthalene by solvent liquids is shown in the following table:—

Carburetting Liquid.	Price per lb.	Price per gallon.		Cost of process per 100 grains of Naphthalene dissolved when Gas is cooled.	
				From 20° C. to 10° C.	From 20° C. to 0° C.
	d.	s.	d.	d.	d.
Alchohol	1·744	1	2	0·936	0·884
Petroleum ether	1·907	1	1	0·829	0·795
Benzene	1·090	0	9½	0·110	0·075
Toluene..	1·526	1	1¼	0·160	0·14
Xylene	0·545	0	4¾	0·067	0·067

The author strongly advocates the use of solvents, such as those enumerated in the foregoing tables, and more particularly recommends that of xylene (solvent naphtha) as the cheapest agent for the purpose. He also further points out that as coal-gas always contains appreciable quantities of the vapours of homologues of benzene, such as toluene and xylene, it is not necessary to use the full quantity required according to the calculations in order to secure the desired effect. As a rule 8·75 grains solvent naphtha per cubic foot of gas, or 1¼ lb. per 1000 cubic feet, will suffice.—G. P. L.

Pumping Gas. By G. J. ROBERTS. (Abstract of Paper read before the American Gas Light Association.)

The author gives the results of a series of experiments on pumping gas with exhausters and Sturtevant blowers, also formula deduced therefrom.

Formulæ:—

Where L = Length of main in yards.
R = Revolutions per minute during test.
R′ = " " when outlet valve closed.
V′ = Volume of gas delivered if no slip in exhauster.
V° = " actually delivered.
H′ = Net head difference.
V = Velocity in feet per minute.
H = Net head at exhauster.
C′ = Net capacity of exhauster.
C = Gross capacity of exhauster.
G = Specific gravity of gas.
Q = Volume of gas per minute.
Ms = Thousands of cubic feet pumped per hour.
C° = Constant.

$$Q = C^\circ \sqrt{\frac{h\,d^5}{G\,L}}.$$

$$HP = \frac{V\,H \times 0{\cdot}036 \times 144}{33{,}000}.$$

$$V' = \frac{Q}{R - R'}. \qquad V = \frac{Q}{R}.$$

Percentage of slip $\frac{C'}{C}$.

Formulæ for Wilbraham's Exhauster:—

$$HP = 0{\cdot}00511 \times H \times Ms.$$

For fan:—

$$HP = 0{\cdot}01 \times H \times Ms.$$

The experiments show that positive exhausters are more efficient than fans, and also that they are most efficient at the maximum speed.

Note.—The author mentions that the low efficiency of the fan was partly due to a restricted inlet.

Test.	Exhauster or Blower used.	Volume of Gas per hour at 60° = Ms.	Revolutions of Exhauster per Ms.	Slip per Ms.	Specific Gravity of Gas = G.	Diameter of Gas main = d.	Length of Main in yards = L.	Pressure at Inlet to Exhauster.	Pressure at Outlet to Exhauster.	Pressure at end of Main.	Net Head Difference = H'.	Indicated Horse-power.	Useful Horse-power.	Efficiency.	Gross Capacity of Exhauster.	Capacity net per Revolution.	H = Net Head at Exhauster.	Horse-power per M per hour per inch pressure.	Constant C°. (In formula for Q.)
						in.		in.	in.	in.	n.				cub. ft.	cub. ft.			
1	Wilbraham's Exhauster	181	87	27	0·62	30	6700	3·9	51·5	48·7	2·8	43·4	22·18	0·51	50	34·3	47·6	·00504	1416
2	"	193·2	82	16	0·62	30	6700	2·8	30·9	27·9	3·0	26·2	14	0·53	50	39·3	28·1	·00484	1450
3	"	211·6	83	12	0·62	30	6700	2·5	19·7	16·1	3·6	19·7	9·67	0·49	50	42·5	17·2	·00541	1465
4	"	145·0	73	27	0·64	30	4760	8·3	51·1	50·1	1·0	36·9	15·2	0·41	52·6	33·1	42·8	·00590	1624
5	"	455·0	182	38	0·64	30	4760	8·0	17·2	6·6	10·6	18·2	11·13	0·61	52·7	41·7	9·2	·00435	1565
6	Sturtevant 8 B Fan Blower	58·8	832	..	0·62	16	3720	5·8	8·5	3·4	5·1	3·34	0·42	0·13	1·1	..	2·7	·02105	1220
7	"	59·1	828	..	0·62	16	3720	5·9	8·5	3·4	5·1	3·20	0·41	0·13	1·2	..	2·6	·02082	1228
8	"	148·3	2131	..	0·62	16	3720	6·2	12·0	4·0	8·0	22·0	6·36	0·29	1·2	..	15·8	·0094	1639

Influence of various Oxides on the Luminosity and Durability of Incandescent Mantles. By HERR W. BRUNO. (Abstract of communication to Zeitschrift für Beleuchtungswesen.)

The author gives the results of some very exhaustive researches on the influence of various oxides employed in the production of incandescent mantles. The experiments quoted were made on mantles impregnated with thorium-cerium solution, with the following added thereto by increments of 0·1 per cent.

THE USE OF—	
Aluminium	Increases the elasticity and refractory qualities of the mantle, but involves a loss of luminosity after a short period of use.
Magnesium and Cadmium	Produce a tendency to split the mantle, but in other respects are similar in their influence to aluminium.
Beryllium	In amounts greater than 0·5 per cent. it causes the mantle to contract and become useless.
Zinc	Reduces luminosity.
Calcium	Causes mantle to contract longitudinally, and reduces light emitted.
Potassium and Sodium ..	Give a pale yellow tinge to light.
Yttrium	Increases brilliancy of mantles on first lighting.
Didymium	Resembles cerium in its effects on the mantles, but reduces luminosity.
Lanthanum	Increases hardness, but give a brownish tinge to the light.
Chromium, Cobalt, Zirconium, Uranium ..	Stiffen mantles, but give the light a peculiar colour.
Lithium	In quantities up to 0·5 per cent. in thorium-cerium solution produces a soft mantle giving a brilliant white light, but is not permanent in its effect.

G. P. L.

The Recovery of Nitrogen in Coal Distillation. By W. CARRICK ANDERSON, D.S.C., and JAMES ROBERTS, F.C.S. (Abstract of paper read before the Scottish Section of the Society of Chemical Industry.)

The authors emphasise the great importance of the subject of the recovery of nitrogen, and consider the subject under the following heads:—

1. The way in which the nitrogen of coal distributes itself on heating, and the conditions under which ammonia is obtained in retorts and ovens.

2. The limits of ammonia production, and the obstacles in the way of reaching these limits.

Nitrogen in Coal. Excluding anthracites, the average quantity of nitrogen present in coals is about 1·4 per cent. or 31·36 lbs. of nitrogen (equivalent to 147·8 lbs. sulphate of ammonia) per ton of coal carbonised.

Mr. Beilby gives the average yield of sulphate of ammonia as:—

From coke ovens ..	19·7 lbs.	= 13·3	per cent. of available (calculated on above basis).
„ blast furnaces	20·2 „	= 13·7	„
„ gas-works	22·4 „	= 15·1	„

Behaviour of the Nitrogen on Heating.—When coals are subjected to a gradually increasing temperature in a closed vessel a considerable loss in weight is experienced before the thermometer reaches 300° C., but the authors have not observed any loss of nitrogen below 333° C. In each of the experiments, alkaline reaction commenced below 480° C. The splint and gas coals of Mid-Lanarkshire begin to yield alkali at what is, comparatively speaking, a low temperature—a fact which is undoubtedly of great value in relation to the development of ammonia recovery in the blast-furnaces of the West of Scotland.

NITROGEN REMAINING FIXED IN COKE.

Name of Coal.	Nitrogen in Coal.	Weight of Coke.	Nitrogen in Coke.	Nitrogen expelled from Coal.	Nitrogen left in Coke from 100 grams Coal.	Per cent. of original Nitrogen left in Coke.
	per cent.	per cent.	per cent.	per cent.	grams.	
Ell coal	1·53	55·37	1·83	0·517	1·013	66·2
Splint coal	1·50	55·14	1·73	0·527	0·973	64·9
Kiltongue coal.. ..	1·65	55·84	1·77	0·661	0·989	59·9
Bannockburn main ..	1·89	69·93	1·80	0·631	1·259	66·6
Kilsyth coking coal..	2·04	66·59	1·79	0·849	1·191	58·4
Lower Drumgray ..	2·12	79·14	1·79	0·693	1·421	67·3

The authors also give the results of some experiments made by them, on the effect produced by adding various alkaline substances to the coals before carbonisation, which are summarised in the following table.

Name of Coal.	Nitrogen in Coal used.	Nitrogen in Coke from untreated Coal.	Percentage of original Nitrogen in Coke.	Nitrogen in NaOH Coke.	Percentage of original Nitrogen in NaOH Coke.	Nitrogen in $Ca(OH)_2$ Coke.	Percentage of original Nitrogen in $Ca(OH)_2$ Coke.	Nitrogen in Na_2CO_3 Residue.	Percentage of original Nitrogen in Na_2CO_3 Coke.
	grm.	grm.	p.c.	grm.	p.c.	grm.	p.c.	grm.	p.c.
Splint coal	0·0150	0·0095	63·3	0·0018	12·3	0·0097	64·7	0·0148	98·7
" "	..	..	..	..	..	0·0097	64·7	..	..
Ell coal	0·0153	0·0101	66·0	0·0036	23·5	0·0116	75·8	0·0140	91·5
Bannockburn main coal	0·0189	0·0125	66·1	0·0140	74·0	0·0126	66·7	0·0158	83·6
Kilsyth coking coal	0·0204	0·0119	58·3	0·0174	85·3	0·0144	70·6	0·0156	76·5

These figures present two very remarkable features:—(1) a fairly complete elimination of the fixed nitrogen is effected by caustic soda in the case of non-coking coals, but none at all in the coking varieties; (2) carbonate of soda causes, in every case, a further fixation of nitrogen, and in the case of the non-coking coals this is equal to over 90 per cent. of the total nitrogen content of the coal; (3) slaked lime produced in all cases very little result,

but invariably showed a tendency towards fixing additional nitrogen in the coke.

Nitrogen set free from Coals.—The experiments made showed that the total nitrogen left behind in the coke was on an average of 64 per cent. The balance of about 36 per cent. is set free in three forms, alkaloidal and other nitrogenous bodies in the tar, ammonia in the liquor, and free nitrogen in the gas. The authors conclude that no part of the nitrogen of coal is liberated in the distillation process as free nitrogen, and its invariable presence in the gaseous products may therefore be set down to a more or less exclusive dissociation of the previously formed ammonia in contact with heated surfaces. The ammoniacal gases evolved from the central portions of the charge having to make their exit through a layer of partially coked material, which is already at a fairly high temperature, while the conditions, so far as the roughness of the solid surface and the rate of passage of the gas are concerned, are almost ideal for bringing about dissociation to the utmost extent, and go a long way to explain the fact that, while for the whole country the average yield of sulphate from gas-works is 22·4 lb. per ton, that from coke ovens is only 19·7 lb.

Ammonia in the Blast Furnace.—The recovery of ammonia from the gases of the blast-furnace presents itself as a special case of what is carried on in a gas-works, apart from the engineering difficulty of dealing with the 130,000 cubic feet per ton as against 10,000 cubic feet in gas-works, the process would present no extra difficulty, were it not for one factor which is most remarkably ignored. So far as avoiding the danger arising from simple dissociation of the alkali is concerned, the gradual descent of the charge in the furnace admits of distillation being carried on for a fairly lengthy period at a low temperature, as compared with that obtained in a gas retort, while, since the gas in rising is continually passing into zones of diminishing temperatures, the alkali does not here incur the risk of dissociation to the same extent as in making its escape from the coke oven. Yet we find that the average yield from blast furnaces is only 20·2 lb. as against 22·4 lb. in gas-works. What is the reason?

A long-continued series of experimental trials established conclusively that the presence of iron ore in the distillation charge was responsible for a very serious falling off in the yield of sulphate of ammonia, and that this was brought about by oxidation of the ammonia by the oxide of iron, a reaction which begins at a fairly low temperature. A sample of splint which gave when distilled about 31·65 lb. of sulphate of ammonia, yielded when treated as nearly as possible under the same conditions of temperature, but in the presence of calcined clay-band ore in the proportions of an ordinary blast-furnace charge, only 23 lb. of sulphate.

Another coal, similarly treated, gave—

When distilled alone .. .. .. 30·73 lb. ammonia sulphate per ton.
" " with iron ore .. 17·11 " "

The authors summarise their conclusions as follows:—

1. When coal is heated, part of the nitrogen contained in the nitrogenous constituents comes off as ammonia in the gases, part goes to form nitrogenous compounds in the tar, the rest remains fixed in the coke.

2. The percentage which is thus evolved as ammonia is dependent partly on the structure of the nitrogenous constituent of the coal, as well as two other factors, the amount of hydrogen available to combine with and carry off the nitrogen, and the period during which the nitrogenous body is exposed to the influence of the hydrogen above a certain temperature.

3. Heating the nitrogen-containing body has no effect alone in dislodging the nitrogen, there must be a simultaneous action of hydrogen or certain hydrogenised compounds.

4. The presence of free nitrogen in the gases got from the distillation of coal amounting frequently to 25 per cent. of the total nitrogen of the coal, is due to the dissociation of ammonia at temperatures over 500° C.

5. The amount of this dissociation is increased by the rise of temperature and by increase in the time during which the gas is exposed to the heat. For this reason, although in a coke oven the charge is subjected to a more gradual heating than in a gas retort, the quantity of ammonia liberated in the lower part of the charge is subjected to dissociation conditions for a longer time in passing upwards through a thick crust of strongly heated coke.

6. In blast furnaces the oxide of iron exercises a destructive effect on the ammonia at comparatively low temperatures; and while, owing to the gradual descent of the raw coal towards the hotter region of the furnace, a considerable part of the ammonia will be formed, and escape before the limit of dissociation is attained, yet the influence of the oxide of iron in the ore, which is active at a very much lower temperature, may be such as to more than counterbalance the benefit derived from these favourable conditions, and bring out the average yield of sulphate at a lower figure.—G. P. L.

Testing Products of Combustion from Furnaces, Boilers, &c. (Abstract of Communication to the Journal des Usines à Gaz, Oct. 20, 1899.)

The communication is devoted to a description of a method devised by Le Chatelier, for detecting the presence of carbonic oxide or oxygen in the waste gases from boiler and retort settings, furnaces, etc.

The method depends upon the property possessed by heated metallic copper of rapidly blackening in the presence of oxygen, and also that the oxide so formed is capable of being reduced to the metallic state by carbonic oxide.

The apparatus consists of an enclosed Argand-Bunsen lamp, with a refractory porcelain central tube, having a film of copper deposited on the upper portion.

The gas to be tested passes through, and round the outside of the heated porcelain tube, and the presence of either gas is indicated on mere inspection of the metallic surface of the tube.—G. P. L.

Gas Analysis. (Abstract of Article in Gas World, April 29, 1899.)

The article is devoted to a description of a method of analysis devised by Dr. OTTO PFEIFFER of Magdeburg.

The apparatus he advocates is shown in Figs. 1, 2 and 3, consists of a Bunte burette B, with the lower end connected to a water-level bottle N, by a

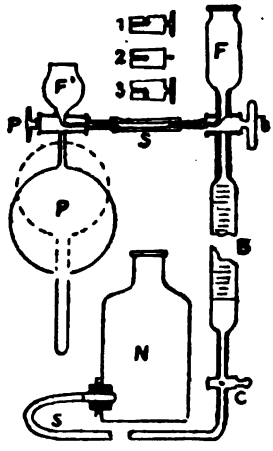


Fig 1

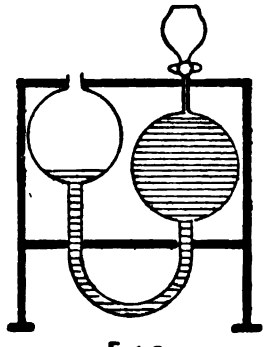


Fig 2.

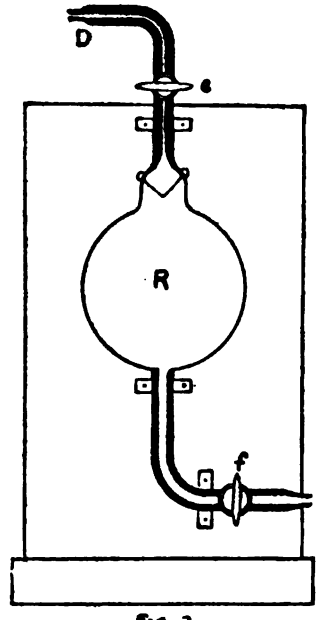


Fig. 3

length of rubber tubing S. The absorption pipette P is connected to the bore of the upper cock *b* by a short piece of tubing S. The water employed is reddened by acidified litmus solution.

In making an analysis, the first step to take is to measure the gas in the burette in the usual way, and then transfer to absorption pipette P (taking care to force out any air in the pipe *b s p*), and retransferring for each component of the gas. The absorption of CO_2 in the pipette P is complete in about one minute, that of heavy hydrocarbons in fuming sulphuric acid in about five minutes (with shaking).

Note.—Care must be taken to wash out the burette with alkaline solution, after the use of fuming sulphuric acid, to remove any fumes left behind.

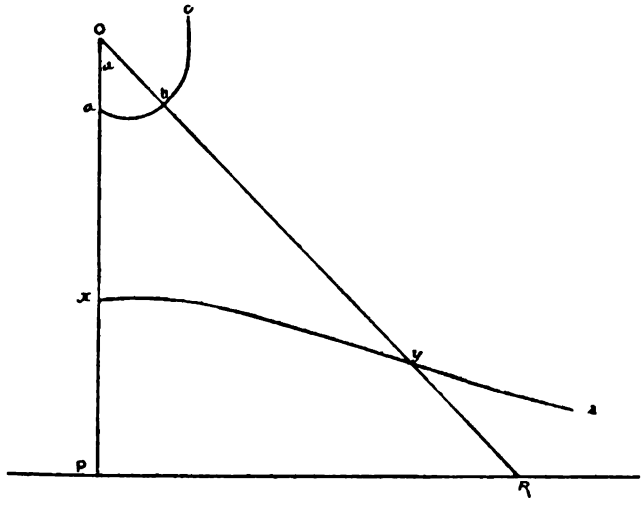
Methane is ascertained by explosion in the pipette R shown on Fig. 3.

Oxygen is determined separately by a calorimetric method devised by Dr. Pfeiffer.—G. P. L.

Graphic Method of Determining Illumination. By HOERST. (Abstracted from the 'Progressive Age's' Abstract of Communication to the Bulletin of Association of Engineers, Liège.)

When it is required to find the illumination at any point of a horizontal plane due to a luminous source whose intensity in every direction is known, the following graphic method gives a rapid means of doing so.

Referring to the figure, the illumination at a point R on the horizontal surface, due to a luminous source O, whose height O P = h, and intensity I in



direction of point is given by the formula I $\cos^3 a^\circ \div h^2$, in which a° is the angle made with vertical by a line joining R to source. To find curve $x\,y\,z$ whose radius vector Oy = 1 gives the luminosity of an ideal source which produces a uniform illumination over horizontal planes. It is necessary to make Oy $\cos^3 a^\circ \div h^2$ = a constant which gives Oy = Ox $\div \cos^3 a^\circ$, so that this curve can be easily drawn. The standard curve $x\,y\,z$ is then a very useful one for the rapid determination of illumination on horizontal planes, due to any other source, such as the one whose luminous characteristic is represented by $a\,b\,c$ in the figure.

The illumination at point R is then Ob $\cos^3 a^\circ \div h^2 = k$ O$b \div$ Oy, in which k = O$x \div h^2$ is a constant. Hence the horizontal illumination is at once determined by multiplying the constant value k by ratio O$b \div$ Oy corresponding to point considered.—G. P. L.

Street Lighting with Incandescent Gas Burners.—Dr. E. SCHILLING, Munich. (Journal für Gasbeleuchtung, 1899, p. 629.)

At last year's Meeting of the Bavarian Society of Gas and Water Engineers it was decided to obtain details of the results of incandescent street lighting by gas, during the previous year, in various Bavarian towns. Replies to inquiries were obtained from eleven towns, and the author was requested to report on the same.

It was found that, in Nuremberg, double burners are generally used in the lanterns, and in Munich only single burners. In the latter town there are 5370 lanterns, with the same number of burners, while, in the former town, there are 6402 incandescent burners in 3349 lanterns. The remaining towns stand between these two extremes, and have generally single burners, with double ones only at the most frequented points.

The lanterns used are partly new special ones and partly old ones converted. At Munich, and to some extent at Warburg, Kletter flame lighters are employed for lighting the burners, while at Nuremberg pilot lights are used, kept always burning, but in the other towns, the lighting flames are extinguished during the time the main burners are alight. As compared with the pilot light, the Kletter lighter is little used, but its economy over a continually burning pilot light, and with gas at 3*s.* per 1000 cubic feet, amounts to 4*s.* 4*d.* per lamp per annum, or, with a lighter extinguished during the time of lighting, to 2*s.* 10*d.* per lamp per annum. The Kletter lighter works quite as reliably and quietly as the flash lights, and interruptions, such as the extinction of the pilot flame by wind, are not likely to occur. The asserted disadvantage, that the small holes in the Kletter lighter become stopped with naphthalene, has not been observed, and is not likely to occur as there is only gas in the lighting tube while the burner is being lighted.

Holophane globes, which disperse the light and prevent the formation of shadows, are used in Munich; the influence of these globes is decidedly good, but their use entails considerable expense, as, in consequence of their unequal thickness they break easily.

In some of the towns spring antivibrators are used to protect the mantles, especially on bridges and in busy parts of the towns.

The cost of adapting existing lanterns for the incandescent light varies in the different towns, between 20*s.* and 30*s.* per lamp. The cost of maintenance is however important, although it has been considerably reduced, since the mantles now cost 2·4 pence each, while they formerly cost 2*s.* 6*d.*

A table is given showing the consumption of mantles and cylinders in the various towns, the figures show great variations. At Wurzburg 9·3 mantles and 4·2 cylinders were required per lamp per annum, while in the small town of Memmingen only 1·1 mantles and 0·4 chimneys were used This depends greatly upon the conditions under which the mantles are changed; for instance, in Regensburg the mantles are changed, in the most frequented streets, so soon as they do not give the required light, and are then further used for side streets. From the replies it appears that the burning hours for the mantles are:—

In Munich	585	hours
„ Nuremberg	567	„
„ Augsburg	662	„

Nuremburg and Regensberg are distinguished by very low cost of maintenance, this is partly due to very cheap mantles and chimneys being used, but also because a large number of burners—principally double ones—are in a relatively small area of the town, while, in Munich, the lighting with single burners extends over the wide outer districts, and, in the inner portion of the town, electric lighting predominates. Generally it may be inferred, from the information given, that, under normal conditions, the cost of maintenance varies between 5s. and 6s. per burner per annum.

Notwithstanding the extensive use of electricity for street lighting in Munich, there is still over three-fourths of the total street area lighted with gas, and all new out-districts are so lighted, so that, at present, the number of gas lamps is nearly as great as it was before the introduction of electric lighting. The electric lighting consists of 830 arc lamps, of which 666 are of ten ampères and 164 five ampères; reduced to ten ampère lamps, there are therefore 748 lamps in use.

		£	s.	d.
These 748 lamps cost in all, per annum		25,078	5	0
Deduct for interest	£2467 1 0			
„ Sinking Fund	783 15 0			
„ Depreciation	2531 6 0			
		5,782	2	0
Net cost of working		19,296	3	0
The gas lighting, with 5075 gas lamps, costs		14,121	19	0
Deduct subvention of the Company		2,400	0	0
Net cost of working		£11,721	19	0

Notwithstanding, therefore, that the electric lighting serves less than one-fourth of the total street area, the cost of it is considerably greater than the three times extended area of gas lighting. If we calculate the working cost per lamp per annum, it is:—

For one 10-ampère arc lamp	£25	16	0
„ one incandescent gas lamp	2	6	0

According to this a 10-ampère arc lamp costs roughly ten times as much as an incandescent gas lamp, and an arc lamp could be replaced by ten incandescent gas lamps, the light from which would hardly be less than from the arc lamp, and they would have the advantage of giving an equally distributed light.

The advantages of the incandescent gas-light for street lighting have been recognised everywhere, and this mode of lighting has attained a prominent position in all towns in which electric lighting is principally used in the most frequented streets and open spaces, and as a light of luxury.—C. G.

Obituary.

Mr. W. H. H. Broadberry, Engineer and Manager of the Tottenham and Edmonton Gas Company, died on October 20th, 1899.

He was born on July 14th, 1831, at Collingham, in Nottinghamshire, and came to London at an early age, shortly after entering the service of the South Metropolitan Gas Company.

Subsequently he was appointed Inspector to the Phœnix Gas Company, at Greenwich, under the late Mr. Robert Hunter, and only resigned this position to take up the management of the Crays Gas Works. He, however, shortly after returned to Greenwich.

In 1855 he received the appointment as Manager to the Southend Gas Company, which position he filled for twenty years, being selected in 1874 by the Board of the Tottenham and Edmonton Gas Company to fill the post of Engineer and Manager of their works, rendered vacant by the death of their late Manager. This position Mr. Broadberry held with much success for twenty-five years, during which time the business of the Company increased nearly sixfold—the output of gas having grown from about 90 millions in 1874 to 522 millions in 1898.

The whole of the manufacturing and distributing (?) were remodelled to Mr. Broadberry's designs, and remain as a monument to his skill and ability.

Mr. Broadberry was always ready to place his large experience at the service of his professional friends, and took a keen interest in the advancement of the Gas Industry generally.

He was a great supporter of the Southern District Association of Gas Engineers, having been one of the founders and a past-president of that Association.

Personally he was extremely courteous and fair-minded, and being of a modest and unostentatious disposition, was highly esteemed by those who knew him best.

He was an original member of this Institution.

Mr. Frank Livesey, born on July 6th, 1844, was the younger son of the late Mr. Thomas Livesey, who was Secretary to the South Metropolitan Gas Company from 1839 to 1871. The subject of this notice was educated at a private school, at Dulwich College, and in the Applied Sciences Department of King's College, London. In October, 1861, he was articled for three years to Mr. Joseph Fogerty, who was at that time engaged on the Coalbrookdale and Craven Arms Railways in Shropshire. He remained with Mr. Fogerty as

an Assistant until 1868, when, in conjunction with his brother, Mr. George Livesey, he designed and superintended the erection of new works for the Tynemouth Gas Company, and of gas-works at Tudhoe in the county of Durham. On the completion of the Tynemouth works he was appointed, in 1870, Engineer to that Company, which post he held for three years.

Mr. Livesey's connection with the South Metropolitan Gas Company began in January 1873, when he was appointed Assistant Engineer under his brother, whom he assisted in the design of the first of the modern large gasholders, capable of containing 5½ million cubic feet. The cost of gasholders was thereby reduced to less than 9*l.* per 1000 feet capacity. In 1882 he succeeded his brother as Chief Engineer, and although the general plan of the new works at East Greenwich had been practically settled, the detail work and the responsibility for their construction were mainly his. The conception of the shallow tank saving a large amount in construction by keeping above the water-bearing strata—the diameter being ten times the depth, or 300 feet to 30 feet—for the twelve million cubic-feet gasholder at East Greenwich was his, and he carried out the difficult work of construction with the Company's workmen.

As Chief Engineer during the great strike of all the Retort-House men in December 1889, his position was one of heavy responsibility, much anxiety and incessant work; his services greatly contributed to the success of the Company in that memorable struggle.

He was engineering correspondent to the Sydney and New South Wales Gas Company, and he did a little outside general engineering and gas-work, but his energies were almost entirely absorbed by the work of the Company with its six manufacturing stations using over 900,000 tons of coal and employing some 4000 workmen. He contributed a number of useful papers to the Gas Associations, and frequently took part acceptably in the discussions. He was selected to serve on technical committees for the investigation of problems connected with gas manufacture and distribution. The heating of retorts by generator firing received his special attention in the direction of making large furnaces to heat a number of settings.

He worked beyond his strength, but he was not willing to give up unless compelled. Often during the last year or two of his life, in the winter time, on foggy days especially, it was not fit for him to leave home, but he would be at his post, and then, in October 1898, on seeing a physician, he was told he must give up his work. Alas! too late.

Mr. Livesey died at Reigate on May 3rd, 1899, at the age of fifty-four. He was a member of the Society of Chemical Industry, and was elected an Associate of the Institution of Civil Engineers in 1869, and became a member in 1883. He leaves a widow and eight children.

Mr. George Ernest Stevenson was born in the year 1848, and was the eldest son of the late George Wilson Stevenson, of Parliament Street, Westminster.

Mr. G. E. Stevenson received his early training in the Locomotive Works of the London, Brighton and South Coast Railway Company, completing it in his father's office.

His first charge of works was the management of the Pembroke Dock Gas-works, at the early age of twenty-two years. He was appointed Engineer to the Aberdare Commoners' Gas Company in the year 1871, resigning, however, that appointment in the year 1878, to take the management of works in Hungary.

On his return to England he obtained the appointment of Engineer and Manager of the Peterborough Gas-works, which he held for eight years, only terminating it on being appointed, in 1885, Engineer of the Buenos Ayres New Gas Company.

At Buenos Ayres he remained for six years, the last two of which were devoted exclusively to consulting work. In addition to the extensive alterations and enlargements for the Buenos Ayres New Gas Company, he designed and erected gas-works in Argentina, at La Plata and Tarana.

The Revolution, however, of 1890 brought to a sudden end the boom of good trade that had for some years been so extraordinary in Argentina, and Mr. Stevenson returned once more to England.

He was shortly afterwards appointed Manager of the Rochdale Road Station of the Manchester Corporation Gas Department. He was later appointed, in addition, Engineer to the Department, and in that capacity designed and carried out all the large extensions and improvements required by the ever-growing demand for gas in that city.

Mr. Stevenson took a lively interest in the welfare of the technical bodies connected with the gas industry, and contributed many useful papers for discussion at their meetings. Perhaps his best was on "The advantage of the Regenerative System of Heating," read before the Gas Institute at Birmingham, in 1881. It was the first clear and lucid statement of the theory of regeneration as applied to heating gas retorts, and many students of the subject have found it invaluable.

On his return from Buenos Ayres, Mr. Stevenson joined the Institution of Gas Engineers, of which he was President in 1898.

He met his death by an accident, on October 30th, 1899, caused by an explosion while superintending extensive alterations to the connecting-pipes on the Rochdale Road Gas-works.

He leaves a widow and seven children—two sons and five daughters Three of the latter are married, and the eldest son is following in his father's footsteps as an Engineer.

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ADDRESS OF THE PRESIDENT. G. C. TREWBY.

PAPERS AND DISCUSSIONS:

THE INSTALLATION OF INCLINED RETORTS AND LABOUR-SAVING APPLIANCES CONNECTED THEREWITH. A. C. MCMINN. (*Plates.*)

A FEW NOTES ON CARBURETTED WATER GAS AT BECKTON. T. GOULDEN. (*Plates.*)

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PAPERS AND DISCUSSIONS:

THE FAILURE OF THE WAGES SYSTEM OF PAYMENT, AND THE REMEDY—PROFIT SHARING. GEORGE LIVESEY.

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THE USE OF OIL FOR CARBURETTING GAS. V. B. LEWES.

NOTES ON THE ENRICHMENT OF COAL GAS WITH LIQUID HYDROCARBON. T. S. LACEY.

THE COMPARATIVE VALUE OF VARIOUS OILS FOR ENRICHING COAL GAS. E. L. PRYCE.

THE TECHNOLOGY OF WATER GAS. T. GOULDEN AND A. M. PADDON. (*Plates.*)

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OTHER PAPERS:

DESCRIPTION OF A FOUR-LIFT GASHOLDER AT BECKTON. G. C. TREWBY. (*Plates.*)

DESCRIPTION OF A THREE-LIFT GASHOLDER AT THE TEMPLE GAS-WORKS, GLASGOW. W. FOULIS. (*Plates.*)

PURIFYING PLANT OF THE STAFFORD CORPORATION GAS-WORKS. J. F. BELL. (*Plates.*)

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HYDRAULIC RETORT STOKING MACHINERY. W. FOULIS. (*Plates.*)

POPULARISATION OF GAS, ESPECIALLY AMONGST SMALL CONSUMERS. J. F. BELL.

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PAPERS AND DISCUSSIONS:

DIFFERENTIAL PRICES FOR GAS. GEORGE LIVESEY.

CARBURETTED WATER GAS. V. B. LEWES.

CARBURETTED WATER GAS APPARATUS. A. G. GLASGOW.

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THE APPLICATION OF "WELDON MUD" TO GAS PURIFICATION. J. J. HOOD AND A. G. SALAMON.

INCLINED RETORTS AT THE COVENTRY GAS-WORKS. G. WINSTANLEY. (*Plates.*)

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NEW RETORT SETTINGS AND FITTINGS AT THE ROCHDALE ROAD GAS-WORKS, MANCHESTER. G. E. STEVENSON. (*Plates.*)
NEW PURIFYING APPARATUS AT THE BOURNEMOUTH GAS-WORKS. F. S. CRIPPS. (*Plates.*)
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ADDRESS OF THE PRESIDENT. ALFRED COLSON.

PAPERS AND DISCUSSIONS:

THE RELATIONS OF CAPITAL AND LABOUR IN GAS-WORKS. GEORGE LIVESEY.

GAS-WORKS EXTENSIONS IN STOCKPORT. S. MEUNIER. (*Plates.*)

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FOULIS-ARROL STOKING MACHINERY AT EAST GREENWICH. J. TYSOE. (*Plate.*)

THE ENRICHMENT OF COAL GAS. J. F. BELL. (*Plate.*)

THE ENRICHMENT OF COAL GAS, AND THE APPLICABILITY THERETO OF THE PEEBLES OIL GAS PROCESS. S. GLOVER. (*Plates.*)

THE WORKING OF THE OXY-OIL GAS PROCESS AT HUDDERSFIELD. W. R. HERRING. (*Plates.*)

THE RELATION OF CARBURETTED WATER GAS TO THE EUROPEAN GAS INDUSTRY IN 1894. A. M. PADDON. (*Plate.*)

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WORKMEN'S FUNDS FOR SICKNESS, ACCIDENT, OLD AGE, ETC. GEORGE LIVESEY.

THE WORK OF THE PHOTOMETRIC STANDARD COMMITTEE. V. B. LEWES. (*Plates.*)

THE MODERN GAS ENGINE: ITS DEVELOPMENT AND APPLICATIONS. G. E. STEVENSON. (*Plates.*)

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ACETYLENE AND ITS ENRICHMENT VALUE. V. B. LEWES. (*Plate.*)

THE MONIER SYSTEM OF CEMENT CONSTRUCTION AS APPLIED TO GAS-WORKS. F. D. MARSHALL. (*Plates.*)

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SLOPING RETORTS AT BRENTFORD. J. HUSBAND.

THE MANUFACTURE OF SULPHURIC ACID BY SULPHATE OF AMMONIA MAKERS. F. W. STEVENSON. (*Plates.*)

PURIFIED AMMONIACAL LIQUOR, AND ITS USE IN GAS PURIFICATION. T. HOLGATE. (*Plate.*)

OTHER PAPERS.

DESCRIPTION OF A THREE-LIFT GASHOLDER AND IRON TANK AT HASTINGS. C. E. BOTLEY. (*Plates.*)

DUPLEX COAL BINS FOR HAND-STOKED RETORT SETTINGS. C. C. CARPENTER. (*Plate.*)

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CONTENTS OF VOLUME VI.
(1896).

ADDRESS OF THE PRESIDENT. WILLIAM FOULIS.

PAPERS AND DISCUSSIONS:

NOTES ON RESIDUALS. C. HUNT. (*Plate.*)

ON THE EFFICIENCY OF THE LONDON ARGAND AT DIFFERENT RATES OF GAS CONSUMPTION, WITH SPECIAL REFERENCE TO ITS USE AS A GAS-TEST BURNER. L. T. WRIGHT.

INCANDESCENT GAS LIGHTING. V. B. LEWES.

THE MEASUREMENT OF GAS IN RELATION TO TEMPERATURE. GEORGE LIVESEY.

THE APPLICATION OF THE EXPANSION OF FLUIDS TO THE CORRECT MEASUREMENT OF GAS PASSING THROUGH METERS. W. W. FIDDES. (*Plate.*)

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PAPERS AND DISCUSSIONS:

THE LUMINOSITY OF FLAME. PROFESSOR SMITHELLS.

NOTES ON CYANOGEN AS A GAS-WORKS RESIDUAL. G. P. LEWIS. (*Plate.*)

THE CARBURATION OF COAL GAS. CHARLES F. BOTLEY AND C. F. BOTLEY. (*Plates.*)

MODERN METHODS OF HANDLING AND STORING COALS. F. D. MARSHALL. (*Plates.*)

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